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A QUARTERLY DEVOTED TO THE BIOLOGICAL AND PHYSICAL SCIENCES OF THE PACIFIC REGION

IN THIS ISSUE: Townsley — *Hawaiian Stomatopod Crustaceans* ● Sherman, Kanehiro, Matsusaka — *Development of Laterite* ● Hanson — *Flukes of Genus* Schistorchis ● Knight and Hull — *Part Three of* Aedes *Mosquitoes of the Philippine Islands* ● Morgan — *Studies in Electrofishing in Sea Water* ● Bank — *Biological Succession in the Aleutians* ● Wilson — *Records of Alaskan* Eurytemora ● Hardy — *Bibionidae of New Zealand* ● NOTES ● INDEX

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Adult and Larval Stomatopod Crustaceans Occurring in Hawaiian Waters[1]

SIDNEY JOSEPH TOWNSLEY[2]

INTRODUCTION

THE STOMATOPODA constitute the only order belonging to the division Hoplocarida of the malacostracan Crustacea. All living forms are included in a single family, the Squillidae, whose characteristics are the same as those of the order. The order, according to Bigelow (1894), may be defined as Crustacea which have these characteristics: the stalked eyes and antennules are borne upon distinct movable segments; the adult rostrum is separated from the carapace by a movable joint; the carapace is small and does not cover the last four thoracic somites; the first five pairs of thoracic appendages are not biramous and serve as accessory mouth parts, with the second pair strongly developed into large raptorial limbs; the last three pairs of thoracic appendages are adapted for walking, are biramous and bear a lateral segment upon the penultimate segment; the abdomen is well developed; filamentous gills are carried upon the exopod of the first five abdominal appendages; the sixth abdominal appendages, the uropods, with the telson, act as a powerful tail fan.

At the present time the six recognized genera have a world-wide distribution, being found in the tropical, subtropical, and temperate waters of the Atlantic, Pacific, and Indian oceans. All six genera are represented in the Hawaiian fauna. Edmondson (1921), reporting upon the stomatopods in the collection of the Bernice P. Bishop Museum, found six genera and eight species from Hawaii: *Squilla oratoria*, *S. alba*, *Pseudosquilla ciliata*, *P. oculata*, *Coronida sinuosa*, *Lysiosquilla maculata*, *Odontodactylus hanseni*, and *Gonodactylus guerini*. Since that time no extensive studies have been made on specimens from Hawaii, but occasional reports of previously recorded species from this region have found their way into the literature. In addition to these eight species which have been again collected during the progress of this study, I have found two species which have not been recorded from this region previously, namely, *Squilla boöps* and an undescribed species of *Squilla*.

Stomatopods are usually found in very shallow water, but some species occur at greater depths. I have collected *Gonodactylus guerini* in Hawaii only at depths over 100 meters, and Kemp (1913) reports that *Squilla leptosquilla* was dredged by the "Investigator" at a depth of 370–419 fathoms. The adults are bottom dwellers where they may burrow into the substrate or inhabit crevices in coral. They are seclusive in their habits and during the day are usually found either in their burrows or but a short distance away. At times they wander some distance from their burrows, as is shown by the fact that they are occasionally captured in crab nets and at submersible lights used for collecting at night. Inasmuch as the burrows are quite deep (a foot or more below the surface), and because the animals retire to the bottom of them at the least alarm, stomatopods are quite difficult to collect; consequently, the group has been studied very little, the most notable works being those

[1] Contribution No. 37, Hawaii Marine Laboratory, Prepared as partial requirement for the M.S. degree. University of Hawaii. Manuscript received November 14, 1951.

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of Miers (1880), Brooks (1886), Bigelow (1894), and Kemp (1913). Of these works, the most useful for the identification of the Hawaiian species has been Kemp's monograph on the Indo-Pacific species.

Stomatopods are carnivorous and readily seize any flesh held in front of their burrows. This behavior has provided the most satisfactory means for capturing them, as they can be lured from their burrows by suspending fish flesh a short distance away and captured when they attack the flesh. Considerable dexterity is necessary, however, as they withdraw rapidly into their burrows. It has been impossible to keep more than one specimen at a time in small aquaria as they are highly cannibalistic.

It is doubtful whether the adults often serve as food for other animals, although they may occasionally be found in the stomach contents of fish; but the planktonic larval stages which compose a substantial proportion of the neritic plankton form a considerable part of the diet of pelagic fishes.

Instead of carrying their incubating eggs attached to the abdominal appendages, as do most Malacostraca, the stomatopods deposit them at the bottom of the burrows where they are aerated by currents of water produced by the abdominal appendages of the parent. These appendages are paddle shaped and conform to the cylindrical shape of the hole. The eggs perish when they are deprived of this constant current of water, and, as the female will not remain with the eggs when placed in an aquarium, no larvae have been reared from the egg in captivity.

The young do not hatch as nauplius larvae. All known forms hatch in an advanced stage which bears many adult characteristics, but it is difficult to assign the early larvae properly because the diagnostic characters do not appear until later.

The larvae are delicate, transparent organisms which lead a planktonic existence. The larval life is long, and they pass through many molts before reaching the adult stage. Notwithstanding their great abundance, only two or three early larval forms have been traced to their adult counterpart. Their long planktonic existence easily accounts for the worldwide distribution of the genera and the presence of species such as *Pseudosquilla ciliata* in the Pacific Ocean, Indian Ocean, Red Sea, and Atlantic Ocean. At present there appear to be only two species which are endemic in Hawaii, namely, *Coronida sinuosa* and *Squilla calumnia* n. sp.

Attempts were made to rear larval specimens, collected in plankton tows, in the laboratory, but this proved to be impossible as their period of survival in captivity was very short, and none of the larvae ever molted while in an aquarium. Because rearing of the larvae was unsuccessful, it was necessary to study specimens collected in plankton tows and at night light stations and material from the stomach contents of pelagic fishes.

The earlier authors such as Miers (1880), in their work on larval stomatopods, were content with bestowing separate generic and trivial names upon the larvae. If the adult genus to which the larval specimens belonged was known, they added the suffix -erichthus to the first syllable of the adult genus plus a trivial designation (except in the case of alima of *Squilla*). Thus *Pseuderichthus communis* Hansen, according to this system of classification, represented the larval form of a species of *Pseudosquilla*. Because no keys to these individual larval species were included, future authors found it difficult to identify specimens in their possession with those which had been previously described, and new larval species were erected to compensate for this. Claus (1872) and Brooks (1886) have done the most notable works on the larval forms. Giesbrecht (1910), Foxon (1932), and Gurney (1942) have reviewed the works of Claus and Brooks and expanded their results to include other unidentified larvae. However, I have found that the material has not been adequately simplified below the level of the genus, because in many cases they have retained the

previously assigned generic and trivial names of the larvae, thus making it difficult to ascertain the relationship of these species to those collected in Hawaii. Most of the larvae belonging to a particular genus resemble one another so closely that it is virtually impossible to place them in their proper specific category without rearing them to maturity. Because of these difficulties, I have not tried to relate the Hawaiian larval forms with those of the previously described species, but where it has been possible I have attempted to correlate them with their proper adult species. The specific identification of the larvae was made in the manner used by Claus (1872) and Brooks (1886) in which three methods were employed: (1) a comparison of larval stages with postlarval forms which show characteristics of both the larvae and adults, in this manner working from the adult back through the larval series to the earliest identifiable stage; this is by far the most accurate means of identification, except, of course, where rearing of the larvae to the adult has been accomplished; (2) a comparison of the distribution of larval forms and known adults in which it is possible to make specific diagnoses with some accuracy in those cases where only one or two adult species are known to occur, but cases may arise in which the adult specimen is unknown; (3) the relative abundance of larval and adult species, although this is the least accurate method used, has proved to be useful when one species is known to be more numerous than others and it is assumed that the larval forms also retain the same relative numerical relationship.

Almost all authors who have worked with larval stomatopods have noted that invariably there are forms present which in no respects bear any resemblance to the adults recorded for the region. This is also true of the material at hand from Hawaii. This would seem to indicate that there are numerous species throughout the world, probably from greater depths, which are known only in their larval stages.

The present study was undertaken because recent investigations on the feeding habits of pelagic fishes have shown that the larval stages of the Stomatopoda rank second in importance as food for certain species of tuna in the Hawaiian area, and that they are significant in the diet of several other pelagic fishes. Inasmuch as the adult stages of the pelagic larvae involved are found on the reefs and shores of the Islands, it is apparent that the general economy of the neritic waters in the vicinity is influenced to some extent by the productivity of the reef and shore fauna. These two points suggest a third, namely, that pelagic fishes may be influenced to venture close to shore because of the increased food supply there.

In order to assess objectively the importance of these larval stages in the general economy of the neritic realm, it is necessary to be able to identify the species involved, so that a rapid qualitative and quantitative analysis of both the plankton and the stomach contents of pelagic fishes may be made. The present problem was designed to accomplish these ends for the Stomatopoda, and it is hoped that the results obtained will prove of use to workers in other fields.

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I wish to express my thanks to Dr. C. H. Edmondson for permitting me to examine the specimens in the Bernice P. Bishop Museum, to Mr. Vernon Brock for making available specimens collected by the Territorial Division of Fish and Game, and to the staff of the Pacific Oceanic Fishery Investigations for providing specimens collected by them. I am indebted to Dr. A. H. Banner for his constant help and criticism on the collection of material and preparation of the manuscript, and to Dr. R. W. Hiatt for suggesting the problem and for criticism of the manuscript. In addition I would like to extend my thanks to Mr. Kenji Ego, Mr. Daniel Yamashita, and Miss Winifred Tseu for their help in collecting specimens.

ADULT HAWAIIAN SQUILLIDAE

The genera of *Squillidae* easily fall into two groups which are distinguished by differences in the ischio-meral articulation of the raptorial claw (second maxilliped). In one group the articulation between the merus and ischium is terminal, whereas in the other the ischium articulates at a point anterior to the proximal end of the merus. This character is the basis for the primary division of the family, with *Squilla*, *Pseudosquilla*, *Lysiosquilla*, and *Coronida* comprising the first group, and with *Gonodactylus* and *Odontodactylus* comprising the latter group. Although the phylogenetic significance of the ischio-meral articulation of the raptorial claw is not clearly understood, the species of each natural group resemble each other far more closely than they do those of the other group.

Squilla is separated from the other members of the first group in that its species all possess longitudinal carinae on the body segments. *Pseudosquilla*, *Lysiosquilla*, and *Coronida* are separated from one another by the shape of the body, the carapace, and the telson, as is indicated in the following key and descriptions. *Odontodactylus* and *Gonodactylus* are readily distinguished because species of *Odontodactylus* possess teeth on the inner margin of the dactylus of the raptorial claw, whereas species of *Gonodactylus* lack such teeth.

To avoid confusion in terminology, Figure 1 presents characteristics used in the key and

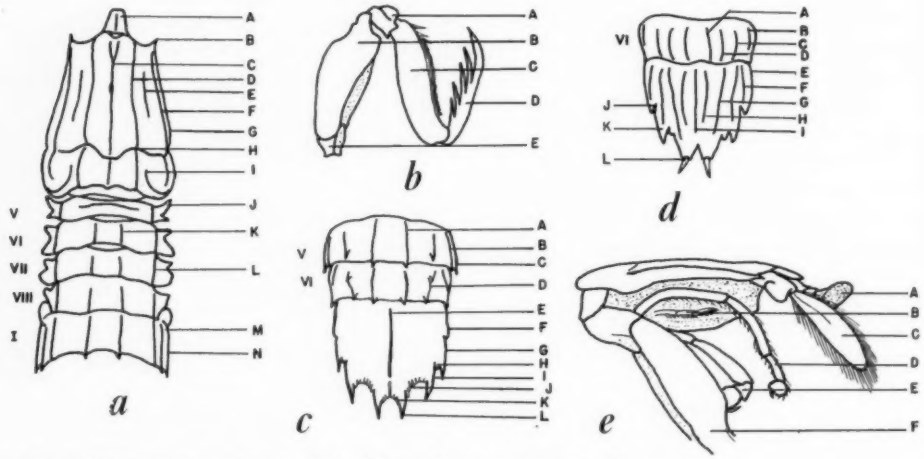

FIG. 1. Diagrams illustrating morphological details and terminology of stomatopods.

a, Rostrum, carapace, exposed thoracic somites, and first abdominal somite of *Squilla*. A–I, Structures of carapace. A, Rostrum; B, anterolateral spine; C, median carina; D, gastric groove; E, intermediate carina; F, lateral carina; G, marginal carina; H, cervical groove; I, posteriorly reflexed marginal carina. J–N, Structures of thoracic and abdominal somites. J, Anterolateral spine of fifth thoracic somite; K, submedian carina; L, intermediate carina; M, lateral carina; N, marginal carina. V–VIII, Fifth to eighth thoracic somites. I, First abdominal somite.

b, Second thoracic appendage (raptorial claw). A, Carpus; B, merus; C, propodus; D, dactylus; E, ischium.

c, Telson and last two abdominal somites of *Squilla*. A–E, Structures of abdominal somites. A, Submedian carina; B, lateral carina; C, marginal carina; D, intermediate carina; E, median carina. F–L, Structures of telson. F, Prelateral denticle; G, lateral tooth; H, lateral denticle; I, intermediate tooth; J, intermediate denticles; K, submedian denticles; L, submedian tooth. V–VI, Fifth and sixth abdominal somites.

d, Last abdominal somite and telson of *Odontodactylus*. A–D, Structures of sixth abdominal somite (VI). A, Submedian carina; B, lateral carina; C, second intermediate carina; D, first intermediate carina. E–L, Structures of telson. E, Marginal carina; F, second lateral carina; G, intermediate carina; H, submedian carina; I, median carina; J, lateral tooth; K, intermediate tooth; L, submedian tooth.

e, Lateral aspect of head and carapace of *Squilla*. A, Cornea of eye; B, mandibular palp; C, antennal scale; D, first thoracic appendage; E, third thoracic appendage; F, second thoracic appendage (raptorial claw).

in the descriptions of the species. These have been partially adapted from Kemp (1913), whose terminology has been employed throughout this work.

Key to Adult Hawaiian Squillidae

A. Raptorial claw with articulation of merus and ischium terminal (Fig. 3*g*), merus grooved ventrally for reception of propodus throughout its length, propodus finely pectinate or with a series of fixed spines along the upper margin, dactylus not inflated at base . . . . . **B**

AA. Raptorial claw with ischio-meral articulation at a point anterior to the proximal end of the merus (Fig. 21*c*), ventral surface of merus grooved for reception of propodus for not more than 0.75 of its length, propodus may or may not be finely pectinate along the upper margin, dactylus inflated at base (**Odontodactylus** and **Gonodactylus**) . . . . . **I**

B. Carapace with well-marked carinae ,cervical groove defined across the dorsal surface; first 5 abdominal somites with longitudinal carinae (**Squilla**) . . . . . **C**

BB. Carapace without well-marked carinae, cervical groove not extending over dorsal surface; first 5 abdominal somites without longitudinal carinae . . . . . **F**

C. Anterolateral angles of carapace armed with short, acute spines; cornea of eyes set obliquely on stalk (Fig. 3*a*), nearly 1.5 times as wide as greatest breadth of stalk, distinctly bilobed . . . . . **D**

CC. Anterolateral angles of carapace rounded, without short acute spines (occasionally with spines in *S. alba*); cornea of eyes set transversely on eyestalk (Fig. 6), slightly wider than the greatest breadth of stalk, very slightly bilobed . . . . . **E**

D. Dactylus of raptorial claw with 6 teeth;[3] body usually more than 100 mm. in length from tip of rostrum to tip of submedian spines of telson . . . . . **Squilla oratoria**

DD. Dactylus of raptorial claw with 5 teeth; body not reaching over 90 mm. in length from tip of rostrum to tip of submedian spines of telson . . . . . **Squilla boops**

E. Submedian teeth on posterior margin of telson with movable tips; 5 or 6 movable spines along outer margin of exopod of uropod; 2 rounded lobes between inner and outer spine of basal prolongation of uropod; body opaque white throughout . . . . . **Squilla alba**

EE. Submedian teeth on posterior margin of telson without movable tips; 8 or 9 movable spines along outer margin of exopod of uropod; 1 rounded lobe near base of inner spine of basal prolongation of uropod; body with definite brown pigment marking carinae and margins . . . . . **Squilla calumnia** n. sp.

F. Lateral margins of exposed thoracic somites and abdominal somites parallel throughout, not increasing in breadth posteriorly; telson with sharp median carina and with lateral carinae (**Pseudosquilla**) . . . . . **G**

FF. Lateral margins of exposed thoracic and abdominal somites not parallel throughout, abdominal somites increasing in breadth posteriorly; telson with median carina low and rounded, and without lateral carinae (**Lysiosquilla** and **Coronida**) . . . . . **H**

G. Inner spine of basal prolongation of uropod longer than outer spine; eyes small and cylindrical; 6 carinae besides median carina on telson . . . . . **Pseudosquilla ciliata**

GG. Inner spine of basal prolongation of uropod shorter than outer spine; eyes flattened, club-shaped; 8 carinae besides median carina on telson . . . . . **Pseudosquilla oculata**

H. Alternating bands of light and dark pig-

[3] The number given for the teeth on the raptorial dactylus throughout this study includes the terminal tooth in all species, except *Odontodactylus hanseni*.

ment throughout length of body; raptorial dactylus with 9 or 10 teeth on inner margin; telson with low, rounded, median carina....**Lysiosquilla maculata**

HH. No alternating bands of light and dark pigment throughout length of body; raptorial dactylus with 4 teeth on inner margin; telson closely studded with large tubercles in definite patterns.....**Coronida sinuosa**

I. Dactylus of raptorial claw with 9 teeth on inner margin; telson with ordinary longitudinal carinae; rostrum with evenly convex anterior border and evenly rounded angles; eyes large, breadth of cornea about equal to 0.5 the length of the carapace; preserved specimens yellowish white or pink.....**Odontodactylus hanseni**

II. Dactylus of raptorial claw without teeth on inner margin; telson with concentric rings of flesh-tipped spines; rostrum trispinous; eyes small, breadth of cornea about equal to 0.125 the length of the carapace; preserved specimens mottled red or reddish brown.....**Gonodactylus guerini**

Squilla oratoria de Haan

Figs. 2, 3*a–k*

Squilla oratoria de Haan, 1844: pl. 51, fig. 2 [figures only]; 1849: 223 [description].
Squilla affinis Berthold, 1845: 26, pl. 3, figs. 1–2.
Squilla nepa Miers, 1880: 25.
Chloridella affinis de Man, 1907: 439.

DESCRIPTION: Carapace considerably narrower anteriorly than posteriorly; nearly twice as long (including rostrum) as greatest breadth anteriorly; conspicuous gastric and cervical grooves, the latter continuous across middorsal region; seven distinct, longitudinal carinae, median bifurcated anteriorly for about 0.25 the distance to cervical groove, intermediate extending nearly entire length of carapace, marginal produced anteriorly into sharp spine and posteriorly rounded and reflexed toward gastric grooves. Rostrum longer than wide, subquadrate, with small median spine, lateral margins convergent anteriorly, not covering ophthalmic somite. Eyes large; cornea bilobed, set transversely on stalk; anterior margin of ophthalmic somite slightly truncate between base of eyestalks (Fig. 3*a*). Merus of raptorial claw articulating terminally with ischium, ventral surface longitudinally grooved throughout its length for reception of propodus; propodus finely pectinate along upper margin and with four sharp movable spines; dactylus not inflated at base, with six long, sharp teeth on inner margin. Propodus of first, third, and fourth thoracic appendages nearly circular, that of fifth subcircular, being slightly longer than wide (Fig. 3*f*, *h*, *i*). Mandibular palp of three segments (Fig. 3*b*, *c*). Free thoracic and abdominal somites dorsoventrally flattened, all possessing longitudinal carinae (first five abdominal somites

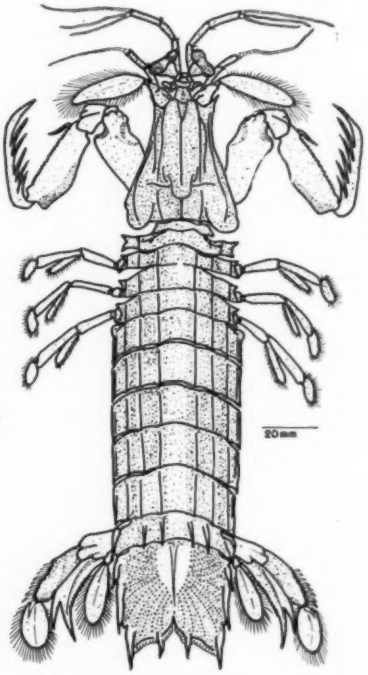

FIG. 2. *Squilla oratoria* de Haan (male).

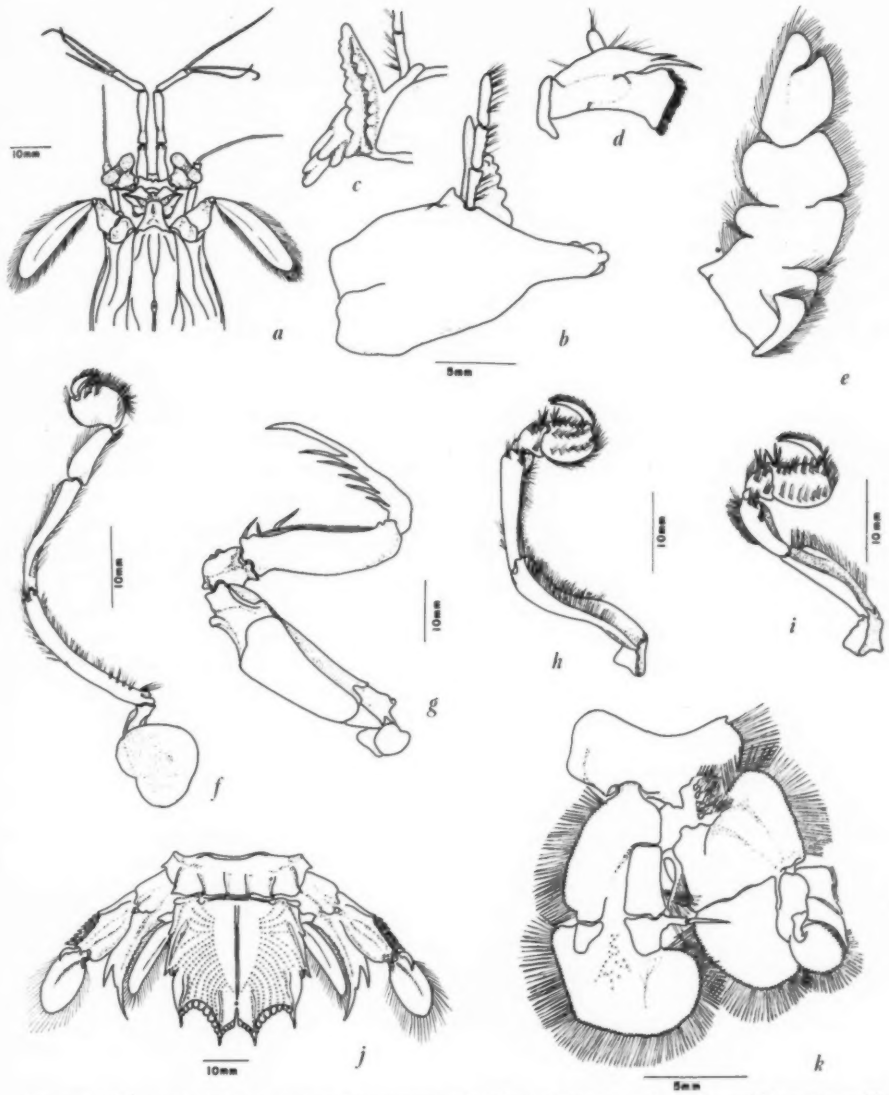

FIG. 3. *Squilla oratoria* de Haan. *a*, Anterior segments of adult; *b*, right pars molaris of mandible and mandibular palp (ventral aspect); *c*, right pars molaris of mandible (dorsal aspect); *d*, right pars incisiva of mandible; *e*, right maxilla; *f*,*g*, right first and second thoracic appendages; *h*, right third and fourth thoracic appendages; *i*, right fifth thoracic appendage; *j*, telson and uropods; *k*, right first abdominal appendage of male.

each with eight carinae); fourth through eighth thoracic somites exposed; intermediate carinae and lateral carinae of abdominal somites 1–5 end in short, sharp spines; sixth abdominal somite with six spines, two submedian, two intermediate, two lateral. Telson with a single median crest, with radiating series of pits on each side; distal margin armed

with three pairs of large immovable teeth, submedian, intermediate, and lateral; three to five submedian denticles, seven to nine intermediate denticles, and a single lateral denticle, also a pair of prelateral denticles. Exopod of uropods with nine movable spines on outer margin. Basal portion of uropod elongated into two spines, inner longer than outer, a small lobe near the outer edge of the inner spine (Fig. 3*j*). Accessory reproductive organ of male shown in Figure 3*k*. The dorsal surface of the specimens is somewhat pitted and a dull mottled tan in color, the ventral surface is highly polished and somewhat lighter in color. Specimens vary from 145 to 200 mm. in length from the anterior end of the rostrum to the extremity of the submedian spines of the telson.

DISCUSSION: Several varieties of this species are recognized, but the Hawaiian specimens seem to fit the characteristics given by Kemp (1913) for those specimens which he had examined from this region. He found that specimens from Hawaii did not seem to fit any of the described varieties and did not attempt to place them in any definite variety.

Three males and three females collected at Oahu were examined. All were collected in regions with a muddy bottom suitable for burrowing. The Bishop Museum has eight specimens, two females collected at Guam, and two males and four females bought at a Honolulu market. All were very similar in appearance, except for small variations in color and size; characteristics which do not seem to be of systematic importance. There seems to be no apparent sexual dimorphism. The only positive means found for distinguishing males from females was the penis at the base of the eighth thoracic appendage, and the accessory reproductive organ of the male found on the first abdominal appendage (Fig. 3*k*).

This species is commonly taken in crab nets by fishermen at the Ala Wai Canal, Honolulu. Occasionally they appear in the Honolulu fish markets, their large size making them desirable for food.

DISTRIBUTION: This species appears to be somewhat more restricted in distribution than are other stomatopods, being reported only from the Hawaiian Islands, Guam, Philippine Islands, inland waters of Japan, and the China Sea.

Squilla boops Kemp

Figs. 4, 5*a–f*

Squilla boops Kemp, 1911 [May]: 97.
Squilla quadraticauda Fukuda, 1911 [August]: 287, pl. 11, figs. 3–5.

DESCRIPTION: Carapace broad anteriorly, breadth behind anterolateral spines exceeds 0.5 the total length including the rostrum; conspicuous gastric and cervical grooves, the latter continuous across the middorsal region; seven distinct longitudinal carinae, median discontinuous anterior to cervical groove, ending in a small pit, marginal produced anteriorly into a short spine and posteriorly rounded and reflexed toward gastric grooves. Rostrum broader than long, lateral margins upturned, rounded and slightly convergent anteriorly, a small median carina. Ophthalmic somite exposed, anterior margin truncate between eyestalks. Eyes large; cornea distinctly bilobed, set obliquely on stalks, considerably more than 0.3 length of carapace; prominent lobe on external aspect of eyestalk. Ischiomeral articulation of raptorial claw terminal; ventral surface of merus longitudinally grooved throughout its length for reception of propodus; carpus with three carinae; propodus finely pectinate along upper margin and with two movable spines proximally; dactylus not inflated at base, with a small ventral tubercle, five teeth on inner margin (Fig. 5*b*). Propodus of third and fourth thoracic appendages rounded posteriorly, those of first and fifth nearly straight and parallel to anterior margin (Fig. 5*a*, *c–e*). Mandibular palp composed of three segments, similar to that of *S. oratoria* (Fig. 3*b*). Free thoracic and abdominal somites dorsoventrally depressed, increasing in breadth posteriorly; all possess-

ing longitudinal carinae; fourth through eighth thoracic somites exposed, lateral margin of fifth produced into an anteriorly directed spine and a rounded posterior lobe, lateral margin of sixth of two rounded lobes, seventh and eight rectangular; first five abdominal somites with eight carinae, the marginal and lateral ending in a short acute spine, all intermediates except that of the first somite ending in spines, submedian of fifth ending in spines; sixth abdominal somite with six carinae, submedian, intermediate, and lateral all ending in spines. Telson with a single median crest terminating in a short spine; radiating series of pits on each side of median crest; distal margin armed with three pairs of immovable teeth, submedian, intermediate, and lateral; three to five submedian denticles, seven to nine intermediate denticles, one lateral denticle, also a pair of prelateral denticles. Exopod of uropods with seven movable spines along outer margin. Basal portion of uropods elongated into two spines, inner longer than outer, a small rounded lobe between the two (Fig. 4). Accessory reproductive organ of male shown in Figure 5*f*. Kemp mentions that the type had the median portion of the carapace, abdomen, and telson covered with small, gray chromatophores. These were not sufficiently abundant to detract from the general coloration, which was yellowish in his type specimen but faintly pink in the specimens at hand. The posterior half of the fifth

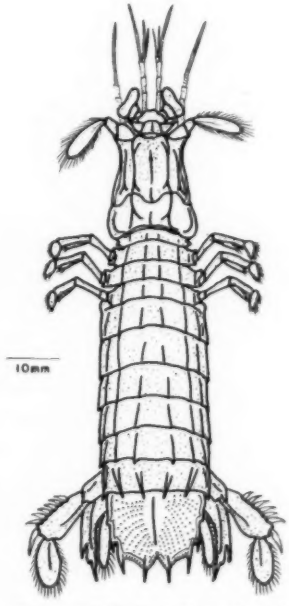

FIG. 4. *Squilla boops* Kemp (male).

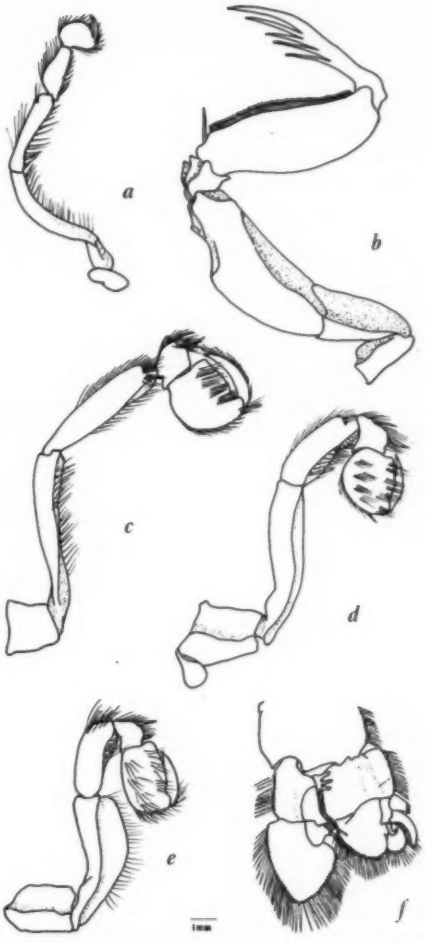

FIG. 5. *Squilla boops* Kemp. *a,b,c,d,e*, Right first, second, third, fourth, fifth thoracic appendages; *f*, right first abdominal appendage of male.

abdominal somite between the lateral and marginal carinae and the outer angles of the sixth somite are black in all three of these specimens, as well as in Kemp's type specimen. No mention of the color of Fukuda's specimen was made. The three local specimens vary from 68 to 75 mm.; Kemp's was 89 mm., and Fukuda's 40 mm.

DISCUSSION: One male and two female specimens of this species have been examined. They were taken from the stomach contents of black skipjack, *Euthynnus yaito* Kishinouye, caught off Moku Manu [Island] off the northeast coast of Oahu. One specimen, a male, was but slightly digested, so the characteristics given by Kemp for this species could be easily recognized.

S. boops can be readily distinguished from *S. oratoria* by its smaller size and by the presence of only five teeth on the raptorial dactylus and only seven spines on the outer margin of the uropod. Early in this study it was thought that these were small specimens of *S. oratoria*, but the differences noted above have shown them to be the adults of Kemp's *Squilla boops*.

Kemp and Fukuda's specimens were both females; thus previously no description has been made of the modified accessory reproductive organ of the male found on the first abdominal appendage. However, Kemp's (1913) figures of the female have been useful in identifying the present specimens, which I consider conspecific.

DISTRIBUTION: The type specimen, a female, was taken by the "Investigator" in the Gulf of Martaban, Burma, at a depth of 67 fathoms. Another female was collected at Matsuwa, Sagami Province, Japan. One male and two females have been obtained from the stomach contents of a black skipjack (*Euthynnus yaito*) caught off Moku Manu (Bird Island), Oahu.

Squilla alba Bigelow

Figs. 6, 7*a–f*

Squilla alba Bigelow, 1893: 103; 1894: 539–541, pl. 22. [Complete description and figures.]

DESCRIPTION: Carapace longer than greatest breadth, slightly narrower anteriorly than posteriorly, with distinct gastric and cervical grooves, with five longitudinal carinae, anterolateral angles rounded and usually armed with short acute spines, posterolateral angles broadly rounded. Rostrum longer than broad, truncate or triangular. Ophthalmic somite partially exposed, anterior margin straight between base of eyestalks, with small rounded process at base of each eye dorsally. Eyes large; cornea set transversely on stalks, only slightly broader than greatest breadth of stalk, about 0.3 total length of carapace, including rostrum. Antennular peduncle about same length as carapace, including rostrum. Ischiomeral articulation of raptorial claw terminal; ventral surface of merus grooved longitudinally throughout its length for reception of propodus; carpus with a blunt median carina; outer margin of propodus finely pectinate, three movable spines near proximal end (only one shown in Fig. 7*b*, other two not visible in this view); dactylus not inflated at base, notched inferiorly, outer margin straight or slightly concave, inner margin armed with six teeth. Anterior and posterior margins of third and fourth thoracic appendages rounded, first and fifth straight and nearly parallel (Fig. 7*a*, *c–e*). No mandibular palp. Fifth through eighth thoracic somites exposed; lateral margin of fifth seen in dorsal view composed of two distinct processes, a long, anteriorly directed spine and a rounded posterior lobe; sixth, seventh, and eighth not bilobed, but rounded. Longitudinal carinae on all exposed somites, eight on first five abdominal somites, none ending in spines; posterolateral margins acute and rounded; sixth abdominal somite with six carinae ending in spines, two submedian, two intermediate, two lateral. Telson with indistinct median carina but a small median spine posteriorly; radiating series of pits on dorsal surface; armed with six marginal teeth, two submedian with movable tips, two intermediate, two lateral; five or six minute submedian spinules, 11 or 12 intermediate,

one lateral. Exopod of uropods with five or six movable spines along their outer margin. Basal portion of uropods elongated into two spines, inner longer than outer, with a distinct, rounded lobe near base of each spine (Fig. 6). First abdominal appendage shown in Figure 7*f*. Body of specimens an opaque white, eyestalks yellow with a very black cornea. Abdominal and thoracic somites and carapace with large, white pigment cells distributed at random over their surface. Telson, seen from above, nearly transparent so that tissue projecting into it can be easily seen and produces the pattern shown in Figure 6. Specimens range in size from 20 to 47 mm. in length.

DISCUSSION: A small female specimen, 20 mm. long, was collected by Mr. Kenji Ego at Kawaihae, Hawaii, in a night light station. This is a very striking species, as the color of the specimens immediately attracts attention. Its shape is also somewhat peculiar, the carapace and exposed portion of the thorax being equal in length and together making up nearly 0.44 of the total length of the body. The entire surface of the body is smooth and polished, interrupted occasionally by distinct carinae. The lateral margins of the fifth thoracic somite with their long, anteriorly directed spines and rounded posterior lobes are also characteristic of this species.

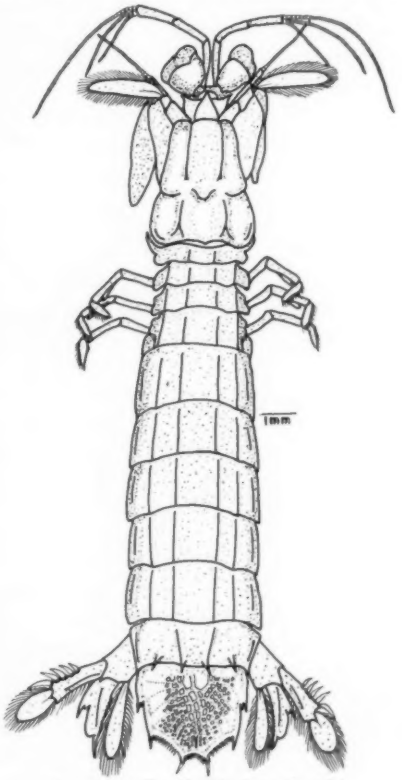

FIG. 6. *Squilla alba* Bigelow (female).

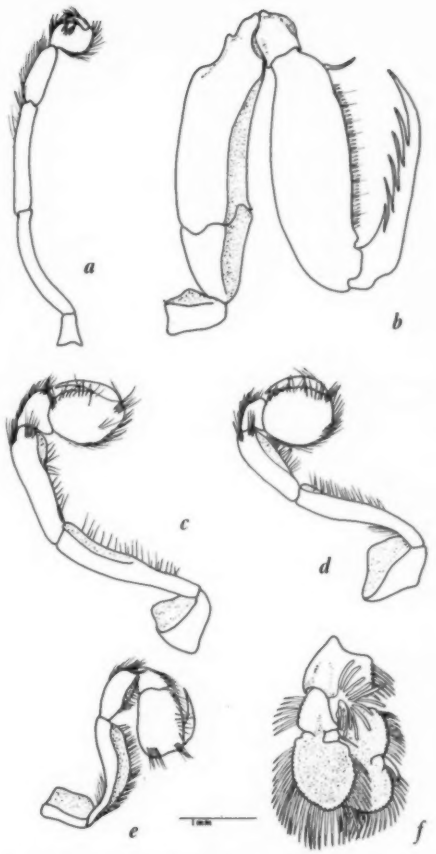

FIG. 7. *Squilla alba* Bigelow. *a,b,c,d,e*, Right first, second, third, fourth, fifth thoracic appendages; *f*, right first abdominal appendage of female.

The type specimen was collected by Bigelow at Bimini Harbor, Bahamas. Edmondson (1921) reported that a female specimen was taken on Waikiki Reef, Oahu. Unfortunately, I have not been able to locate this specimen in the Bishop Museum for comparison with the specimen taken at Kawaihae. Edmondson states that the specimen which he collected agreed with Bigelow's previous description for the species. The Kawaihae specimen agrees with Bigelow's description in color, shape of the eyes, general body proportions, shape of the lateral margin of the fifth thoracic somite, shape of the telson, and the presence of two lobes between the inner and outer spines of the uropods. However, there are certain characteristics in which the specimens differ considerably. Bigelow's type possesses definite longitudinal carinae on the carapace, the rostrum is truncate, the anterolateral angles of the carapace are rounded and armed with a short spine, and the outer margin of the uropods is armed with six movable spines. The Kawaihae specimen, on the other hand, does not have any carinae on the carapace, the rostrum is distinctly triangular, the anterolateral angles of the carapace are rounded and unarmed, and the outer margin of the uropods is armed with only five movable spines. I believe that these differences are due to the relatively immature condition of the Kawaihae specimen, and that it is probably the last postlarval stage of this species. It is possible that the subsequent molt would reconcile the differences between this and the Bimini specimen.

Bigelow makes little note of the submedian spines on the posterior margin of the telson. His figure (1894: pl. 22) is indistinct, but there appears to be a line indicating that they possess movable tips. In the Kawaihae specimen the tips of these spines are unquestionably movable.

No male specimens have been reported. The largest of Bigelow's specimens was 41 mm., Edmondson's was 47 mm., and the Kawaihae specimen is considerably smaller, being only 20 mm. in length.

DISTRIBUTION: The type specimen was collected in calcareous sand at Bimini Harbor, Bahamas. In the Hawaiian Islands one specimen was taken from dead coral on Waikiki Reef, Oahu, and another at Kawaihae, Hawaii, at a night light. These are the only records known for this species.

Squilla calumnia n. sp.

Figs. 8, 9*a–f*

DESCRIPTION: Carapace, excluding rostrum, about as long as greatest breadth; slightly narrower anteriorly than posteriorly; distinct gastric grooves and cervical groove; median, intermediate, lateral, and marginal longitudinal carinae present, median discontinuous and bifurcated anterior to cervical groove, lateral posteriorly reflexed toward gastric groove; anterolateral and posterolateral angles unarmed and rounded. Rostrum broader than long, truncate, small median carina, lateral margins upturned and rounded anteriorly. Ophthalmic somite exposed, anterior margin concave between base of eyestalks. Eyes large; cornea set transversely on stalks, only slightly broader than greatest breadth of stalk, about 0.25 total length of carapace, including rostrum. Antennular peduncle about same length as carapace, excluding rostrum. Ischio-meral articulation of raptorial claw terminal; ventral surface of merus longitudinally grooved throughout its length for reception of propodus; carpus with median and lateral carinae; propodus finely pectinate along outer surface, three movable spines near proximal end; dactylus not inflated at base, outer margin slightly concave, armed with six teeth. Anterior margin of propodus of third, fourth, and fifth thoracic appendages straight (Fig. 9*c–e*), posterior margins rounded; propodus of first thoracic appendage nearly circular (Fig. 9*a*). Mandibular palp composed of two segments. Fifth through eighth thoracic somites exposed, with longitudinal carinae; lateral mar-

gin of fifth, seen in dorsal view, composed of two distinct processes, anteriorly directed spine and nearly straight posterior spine; lateral margin of sixth nearly straight, angular; seventh rounded posteriorly. Eight longitudinal carinae on first five abdominal somites, submedian, intermediate, lateral, marginal; all marginal carinae terminating in a short acute spine; sixth abdominal somite with six carinae, all ending in spines, two submedian, two intermediate, two lateral. Telson with median carina, ending in a small median spine posteriorly; radiating series of pits on each side

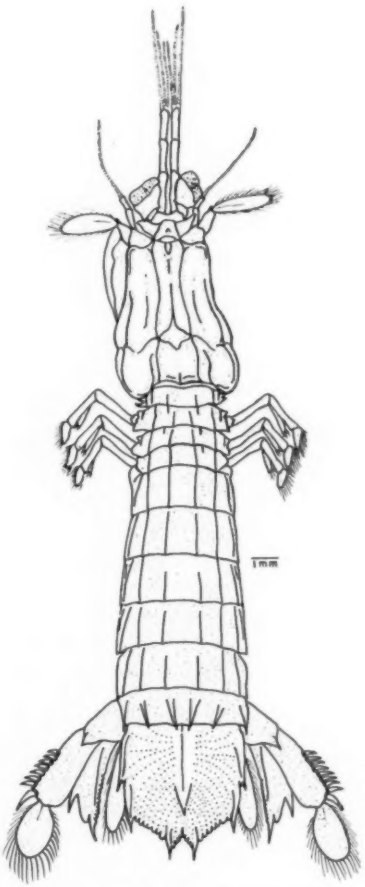

FIG. 8. *Squilla calumnia* n. sp. (female).

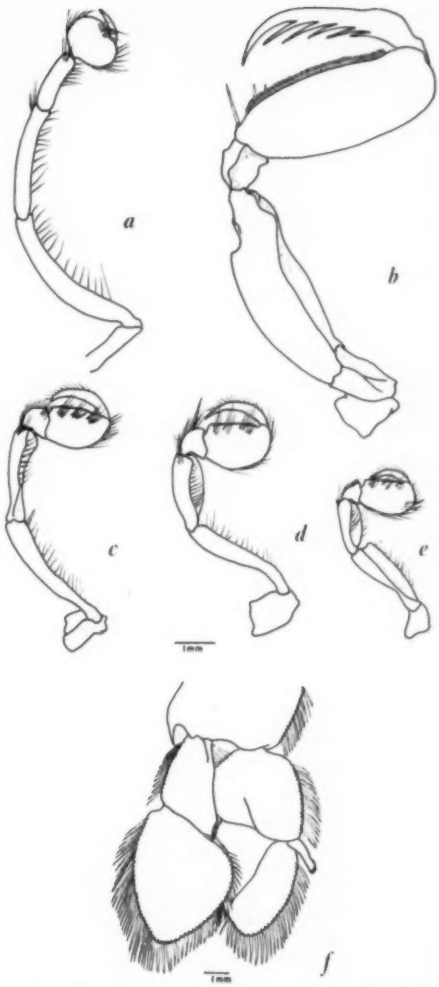

FIG. 9. *Squilla calumnia* n. sp. *a,b,c,d,e*, Right first, second, third, fourth, fifth thoracic appendages; *f*, right first abdominal appendage of female.

of median carina; armed with six teeth, two submedian, two intermediate, two lateral; four submedian denticles, seven intermediate denticles, one lateral denticle. Outer margin of exopod of uropods with eight movable spines on one side, nine on the other. Basal portion of uropods elongated into two spines, inner longer than outer, distinct rounded

lobe near base of inner. First abdominal appendage shown in Figure 9*f*. The coloration of the specimen is sufficient to distinguish it from others which I have examined. The ground color is an opaque white, which is partially obscured by dark-brown chromatophores along the posterior border of the thoracic and abdominal somites and which also clearly mark all the longitudinal carinae of the body. The cornea of the eyes is a deep black, the eyestalks retaining the opaque white of the body. Specimen 26 mm. long.

TYPE LOCALITY: A single male specimen 26 mm. long was collected by the Territorial Division of Fish and Game at a night light station at Hilo Dock, Hilo, Hawaii.

DISCUSSION: Although the penis which is located at the base of the eighth thoracic appendage is present, the specimen is apparently immature, as the accessory reproductive organ on the endopod of the first abdominal appendage is undeveloped. In spite of this condition I feel that the other characteristics are sufficiently distinct for the separation of this specimen from the other species in this genus.

At first glance this species and *Squilla alba* appear to be very similar; but the immovable submedian spines along the outer margin of the telson, the more numerous spines along the outer margin of the uropods, the shape of the lateral margin of the fifth thoracic somite, and the single lobe at the base of the inner spine of the uropod will serve to distinguish this species from *S. alba*. The rounded anterolateral angles of the carapace, the large globular eyes, and the six teeth on the raptorial dactylus are shared by both these species and will serve to separate them from the other members of this genus.

The fifth thoracic somite in this specimen appears to be composed of two distinct processes when seen from above, but it is different from others showing this same condition. In others, e.g., *S. laevis* Hess (1865), *S. hieroglyphica* Kemp (1911), and *S. alba* Bigelow (1893), there is a spine directed anteriorly and a rounded posterior lobe. Here both processes are distinctly angular, the anterior spine curved forward, the posterior one projecting laterally. The shape of the sixth thoracic somite is distinctive in this species as well, in that the others have rounded lateral margins or are distinctly bilobed.

TYPE SPECIMEN: U.S.N.M. 93097.

Pseudosquilla ciliata (Fabricius)

Figs. 10, 11*a–m*

Squilla ciliata Fabricius, 1787: 333.
Cancer ciliatus Linnaeus, 1790: 2990.
Cancer (*mantis*) [sic] *ciliatus* Herbst, 1796: 102.
Squilla stylifera Lamarck, 1818: 189.
Squilla quadrispinosa Eydoux and Souleyet, 1841: 262, pl. 5, fig. 1.
Pseudosquilla stylifera Dana, 1852: 622, pl. 12, figs. 4a–e.

DESCRIPTION: Carapace longer than greatest breadth, slightly narrower anteriorly than posteriorly with conspicuous gastric grooves, cervical groove wholly absent, lacking carinae, anterolateral and posterolateral angles unarmed and rounded. Rostrum rounded anteriorly, about as wide as long, covering the ophthalmic somite. Eyes tubular, cornea following long axis of stalk (Fig. 11*a*). Merus of raptorial claw articulating terminally with ischium, ventral surface grooved throughout its length for reception of propodus; propodus with fine pectinations along outer margin and with four movable spines near proximal end; dactylus with three (sometimes four) long, sharp teeth. Propodus of fifth thoracic appendage subcircular, slightly longer than wide (Fig. 11*i*). Mandibular palp of three segments. Free thoracic and abdominal somites compressed, all lacking longitudinal carinae; sixth, seventh, and eighth thoracic somites exposed; posterolateral angles of abdominal somites with small, sharp spines; sixth abdominal somite with four spines, two submedian, two intermediate. Telson with seven carinae, one median, two submedian, two

intermediate, two lateral; armed with six spines, two submedian with movable tips, two intermediate, two lateral; no submedian denticles, two intermediate denticles, single lateral denticle. Exopod of uropods with nine (sometimes ten) movable spines on outer margin. Basal portion of uropod elongated into two spines, inner longer than outer. Accessory reproductive organ of male shown in Figure 11*l*. Specimens vary from 35 to 85 mm. in length.

DISCUSSION: Fifty-eight specimens of this well-known species were examined, of which 23 were males and 35 were females. All were collected from the reefs around Oahu in water not over 2 fathoms deep. This species represents the dominant form of the Hawaiian Islands. It has been collected from both Kauai and Hawaii where it seems to be as abundant as it is at Oahu. The species appears to prefer the rough substrate of the large exposed reef flats such as those found in Kaneohe Bay, Oahu. It has not been found in those regions having a substrate of coarse shifting sand or strong wave action.

There appears to be no clearly defined sexual dimorphism, and the only definite means that I have found for distinguishing males from females lies in the penis found at the base of the eighth thoracic leg (Fig. 11*j*) and the accessory reproductive organ of the male found on the first abdominal appendage (Fig. 11*l*). Specimens exhibit all degrees of coloring from an olive drab through yellow to a light tan with bright red, blue, and yellow chromatophores. The dactyli of the thoracic appendages are, in most cases, light rose.

According to Brooks (1886) the Atlantic specimens of this species differ in certain small details from those which are found in the Indo-Pacific region. Borradaile (1899) named the Atlantic specimens var. *occidentalis*, but later workers such as Tattersall (1906) and Kemp (1913) have shown that the characters used by Borradaile are to be found in the Indo-Pacific specimens as well. The specimens from the Hawaiian Islands also appear

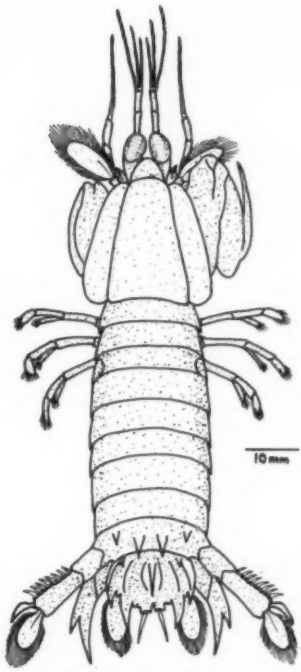

FIG. 10. *Pseudosquilla ciliata* (Fabricius) (male).

to be quite variable, but this variability is not sufficient to warrant their being placed in any other group. I have examined three specimens from Kaneohe Bay, Oahu, in which there were ten spines rather than nine on the exopod of the uropod; and one specimen in which there were nine spines on one side and ten on the other. Two specimens in the collection have the outer spine of the basal prolongation of the uropod longer than the inner. This is a character which has been considered to be specific for *P. oculata* (Brullé), but all other characters of this specimen are those of *P. ciliata*.

Specimens vary in length from 38 to 85 mm. Generally this species is somewhat larger than its congener, *P. oculata*, and in the field they can usually be distinguished in this way.

DISTRIBUTION: There are 12 species of *Pseudosquilla*, nine of which are found in the Indo-Pacific region. *P. ciliata* and its Hawaiian

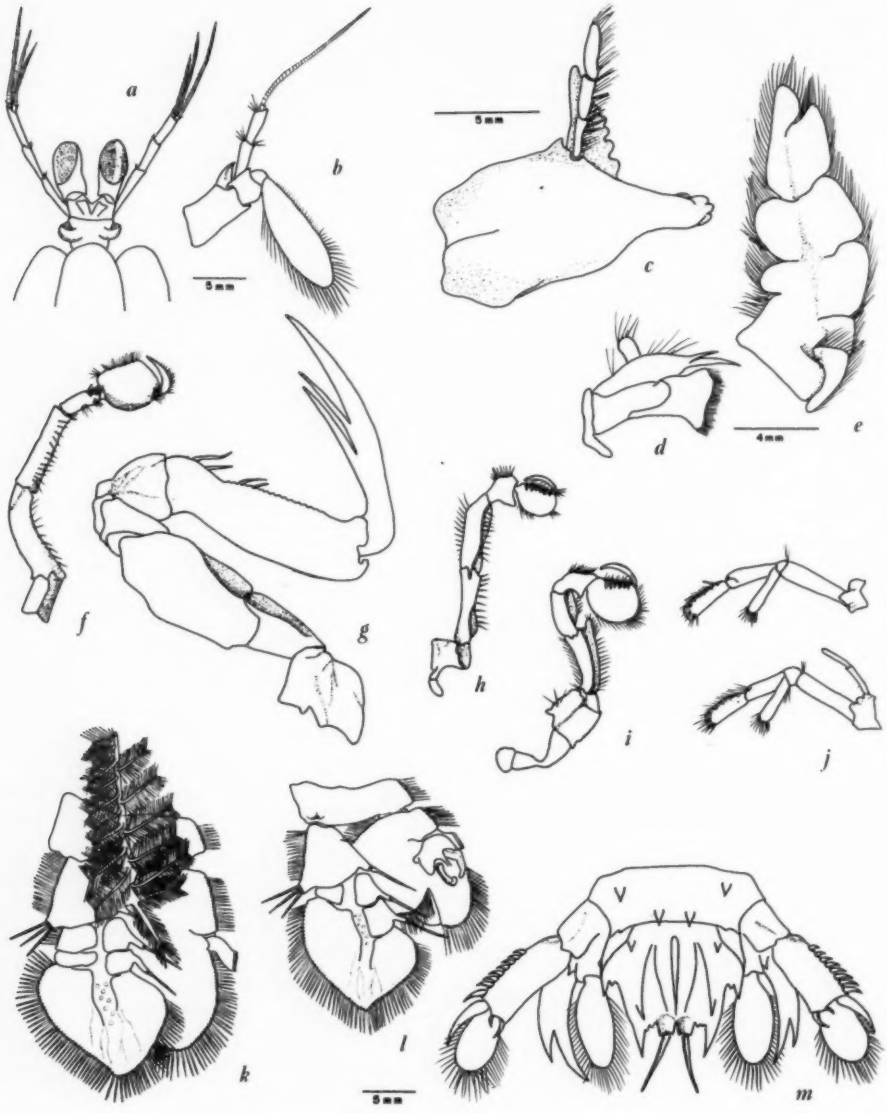

FIG. 11. *Pseudosquilla ciliata* (Fabricius). *a*, Anterior segments with rostrum removed; *b*, right antenna with scale; *c*, right pars molaris of mandible and mandibular palp; *d*, right pars incisiva of mandible; *e*, right maxilla; *f*,*g*, right first and second thoracic appendages; *h*, right third and fourth thoracic appendages; *i*, right fifth thoracic appendage; *j*, eighth thoracic appendage of female (top) and male showing penis (bottom); *k*,*l*, right first abdominal appendages of female and male; *m*, telson and uropods.

relative, *P. oculata*, are both known from the Pacific, Indian, and Atlantic oceans. Ordinarily they are found in the intertidal area in these regions, but Bigelow (1891) reports that *P. ciliata* was collected at a depth of 20–23 fathoms. *P. ciliata* has been reported from the Hawaiian Islands, Fiji Islands, Solomon Islands, Loyalty Islands, Japan, New Britain, New Guinea, Red Sea, Madagascar, Bermuda, Florida Keys, Puerto Rico, and St. Thomas.

Pseudosquilla oculata (Brullé)

Figs. 12, 13

Squilla oculata Brullé, 1836: 18, fig. 3.
Squilla monodactyla A. Milne-Edwards, 1878: 232.
Pseudosquilla oculata Miers, 1880: 110, pl. 3, figs. 3, 4.
Pseudosquilla monodactyla Miers, 1880: 110, pl. 3, figs. 1, 2.

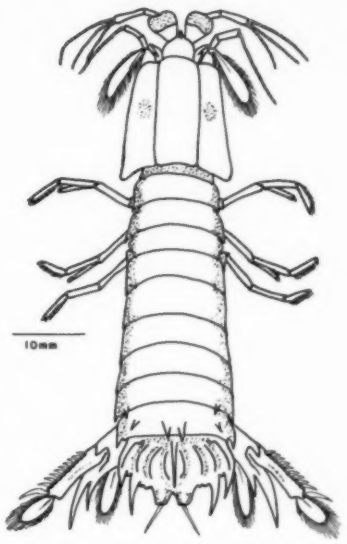

FIG. 12. *Pseudosquilla oculata* (Brullé) (male).

DESCRIPTION: Carapace longer than greatest breadth, slightly narrower anteriorly than posteriorly, with conspicuous gastric grooves, cervical groove wholly absent, lacking carinae, anterolateral and posterolateral angles unarmed and rounded. Rostrum with small median spine, about as wide as long, covering ophthalmic somite. Eyes flattened, appearing somewhat club-shaped rather than tubular (compare Figs. 11*a* and 12), cornea set transversely on stalk. Merus of raptorial claw articulating terminally with ischium, ventral surface grooved longitudinally throughout its length for reception of propodus; propodus with fine pectinations along upper surface and with four movable spines near proximal end; dactylus with three long, sharp teeth. Propodus of fifth thoracic appendage subcircular, slightly longer than wide. Mandibular palp of three segments. Free thoracic and abdominal somites compressed, all lacking longitudinal carinae; fifth, sixth, seventh, and eighth thoracic somites exposed; posterolateral angles of abdominal somites with small, sharp spines; fifth abdominal somite with two sublateral spines; sixth abdominal somite with two submedian and two sublateral spines. Telson with nine carinae, one median, two submedian, two intermediate, two sublateral, two lateral; armed with six spines, two submedian with movable tips, two intermediate, two lateral; no submedian denticles, two intermediate denticles, single lateral denticle. Exopod of uropods with ten (sometimes 11) movable spines along outer margin. Elongated basal portion of uropod with outer spine longer than inner (Fig. 12). Accessory reproductive organ of male shown in Figure 13. All specimens were a mottled tan and all possessed a dark spot on the lateral edges of the carapace, as noted by Kemp (1913). The dactyli are tipped with rose. Specimens vary from 35 to 70 mm. in length.

DISCUSSION: This species superficially resembles the more common *P. ciliata*. In Hawaiian waters the two species are commonly found in the same habitat, and, except through close scrutiny, *P. oculata* may often be mistaken for *P. ciliata*. The eyes of this species are very characteristic in shape and contrast

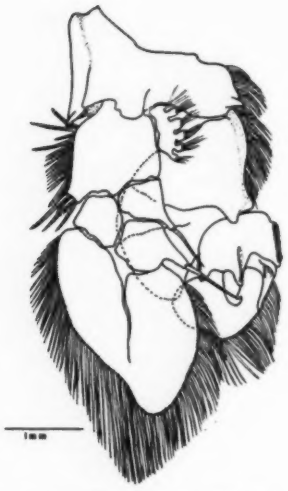

FIG. 13. *Pseudosquilla oculata* (Brullé), right first abdominal appendage of male.

well with those of *P. ciliata* (cf. Figs. 11*a* and 12). The spine-tipped rostrum, the extra pair of carinae on the telson, and the longer outer spine of the uropod will all serve to place specimens in this species.

This species is common in Hawaii: the Bishop Museum collection has five males and six females, and in addition I have examined one male and four females. The largest specimen was a male 70 mm. long, and the smallest was 35 mm. long. All specimens were collected at Oahu in shallow water together with specimens of *P. ciliata*.

Variability in color and form does not seem to be pronounced in this species. One specimen has 11 spines on the outer margin of the exopod of one uropod and 10 on the other. This variation parallels the condition found in *P. ciliata* and indicates that this chracteristic is quite variable.

There is no clear sexual dimorphism. The accessory reproductive organ on the first abdominal appendage of the male is shown in Figure 13. If it is compared with Figure 11*l*, it can be seen that both *P. oculata* and *P. ciliata* are very similar with respect to this structure. Possibly this indicates strong affinities.

DISTRIBUTION: This species and *P. ciliata* are the only members of this genus which have been found in the Hawaiian Islands. As mentioned previously, *P. oculata* is found in the same environment as *P. ciliata*. Specimens are recorded from Samoa and Hawaii in the Pacific, from the Macclesfield Bank in the South China Sea, from Mauritius in the Indian Ocean, and from the Cape Verde Islands and Madeira in the Atlantic.

Lysiosquilla maculata (Fabricius)

Figs. 14, 15*a–g*

Squilla arenaria terrestris or *locusta* Rumphius, 1705: 4, pl. 3, fig. E.
Squilla maculata Fabricius, 1793: 511.
Cancer (*mantis*) [sic] *arenarius* Herbst, 1796: 96, pl. 33, fig. 2.
Squilla arenaria Randall, 1839: 146.

DESCRIPTION: Carapace nearly as broad as long, anterior breadth equal to posterior breadth, smooth, strongly convex from side to side, gastric grooves distinct, cervical groove obsolete or wholly absent, no longitudinal carinae, anterolateral and posterolateral angles broadly rounded. Rostrum broader than long, smooth, lateral margins convergent anteriorly to an acute but blunt apex, small longitudinal carina on anterior one third. Ophthalmic somite anteriorly exposed, dorsally produced into a pair of lobes terminating acutely on each side of rostral apex. Eyes large; cornea set obliquely on stalk, breadth about equal to greatest length of cornea and stalk combined. Antennular peduncle with small acute dorsal spine, less than one-half length of carapace, excluding rostrum. Ischio-meral articulation of raptorial claw terminal; merus grooved ventrally throughout its length for reception of propodus; carpus with blunt dorsal carina terminating in a sharp spine which overhangs anterior margin; propodus finely pectinate on upper margin, four movable spines near proximal end; dactylus slender, 9 to 11 teeth (usually 10), outer margin straight or slightly

concave (Fig. 15*d*). Propodus of third and fourth thoracic appendages orbicular with two weak spines at proximal end, those of first and fifth nearly rectangular and lacking spines (Fig. 15*c*, *f*). Fourth through eighth thoracic somites exposed, lateral margins rounded, lacking longitudinal carinae. Abdominal somites depressed; first through fifth lacking longitudinal carinae, increasing in breadth posteriorly; sixth narrower than preceding somites, with distinct grooves on each side of mid-line. Telson broader than long, convex dorsally, concave ventrally, both sides marked by a feeble median triangular elevation limited by a pair of posteriorly convergent

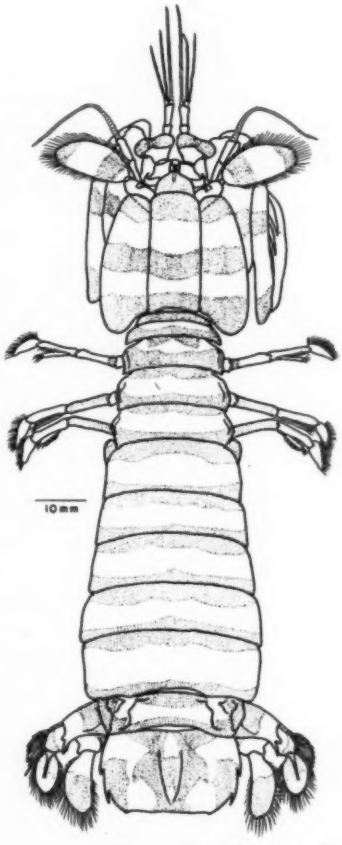

FIG. 14. *Lysiosquilla maculata* (Fabricius) (female).

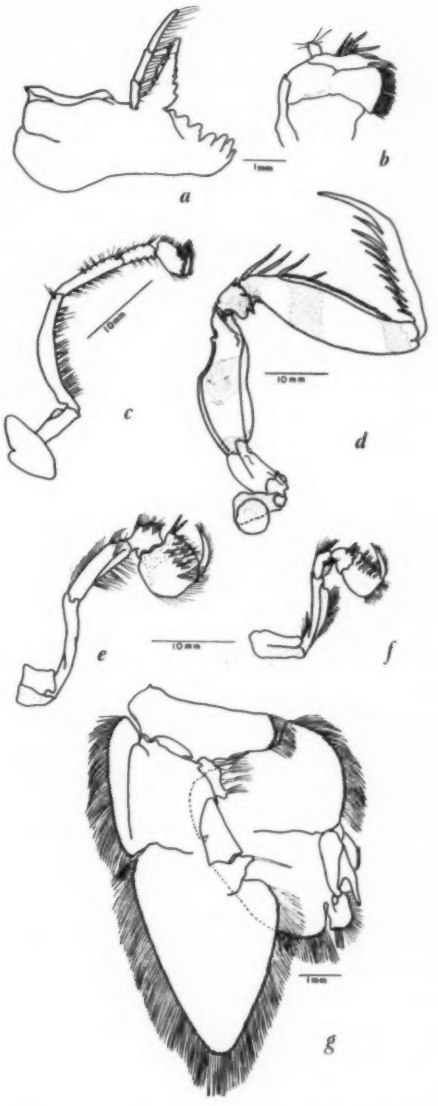

FIG. 15. *Lysiosquilla maculata* (Fabricius). *a*, Right pars molaris of mandible and mandibular palp; *b*, right pars incisiva of mandible; *c*,*d*, right first and second thoracic appendages; *e*, right third and fourth thoracic appendages; *f*, right fifth thoracic appendage; *g*, right first abdominal appendage of male.

grooves; sometimes marked by patches of pits rather regularly disposed near lateral margins; posterior margin indistinctly notched in mid-line with three pairs of blunt lobes, the two outermost generally sharper and more conspicuous than the inner. Inner dorsal edge of peduncular segment of uropods ending in short spine; exopod of uropods with eight or nine movable spines; basal portion of uropod elongated into two long spines, inner nearly twice length of outer, but obscured dorsally. Modified first abdominal appendage of male shown in Figure 15*g*. Animals are marked by alternating series of light and dark bands throughout the length of the body. Specimens vary in length from 69 to 283 mm.

DISCUSSION: This species is very readily identified. All specimens which have been hitherto reported, as well as those which I have examined, have possessed the characteristic dark transverse bands shown in Figure 14. In large female specimens this appears to be a secondary sexual characteristic, inasmuch as the carapace, free thoracic somites, and sixth abdominal somite are almost entirely blue-black. Nearly always in males there are alternating dark and light bands with the telson having a pattern which may vary from that shown in the figure but which usually has dark central and lateral areas. Preserved specimens retain the coloration, but the dark pigment becomes a brownish black.

There appear to be other characteristics showing a sexual dimorphism in this species. Miers (1880) and Kemp (1913) record several large females in which the carpus and the basal part of the raptorial propodus bear tufts of long hairs, and the latter with only two movable spines at its proximal end instead of four. The raptorial dactylus in these cases is also reported by them to have only a series of eight or nine denticles rather than the long teeth usually found there; however, none of the specimens which I have examined has shown these modifications. Evidently this is due to the relatively small size of the female specimens which I have examined compared with those which they report as having these modifications.

This species and *Squilla oratoria* are the two largest stomatopods found in the Hawaiian Islands. I have examined six males and three females ranging from 70 to 185 mm. from the tip of the rostral spine to the posterior border of the telson. Other authors have reported specimens ranging from 69 to 283 mm.

Lysiosquilla maculata seems to occur in shallow water with a sandy or muddy substrate where it may burrow easily. All those specimens which I have examined had been collected in the fine silt on the reefs at Oahu and Hawaii. Mr. Kenji Ego (personal communication) reports that they occur in abundance in the mud flats at Kawaihae, Hawaii.

DISTRIBUTION: This species is widely distributed throughout the Indo-Pacific. In the Pacific it has been reported from the Hawaiian Islands, Marquesas Islands, Samoa, Fiji, Philippine Islands, and the Dutch East Indies.

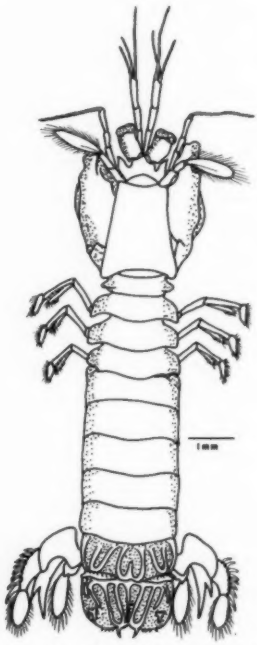

FIG. 16 *Coronida sinuosa* Edmondson (female).

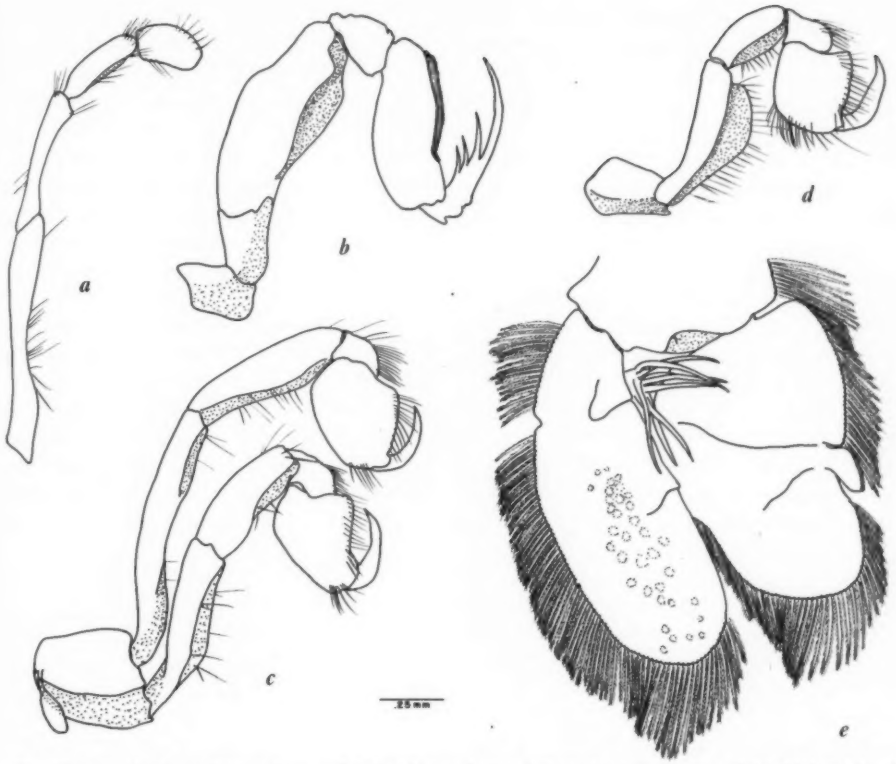

FIG. 17. *Coronida sinuosa* Edmondson. *a*, *b*, Right first and second thoracic appendages; *c*, right third and fourth thoracic appendages; *d*, right fifth thoracic appendage; *e*, right first abdominal appendage of female.

In the Indian Ocean it has been reported from Penung, Tuticorin, Madras, Mysore, and Durban. In the Atlantic Ocean adult specimens have been collected at Antigua, Dutch West Indies, and larvae from near the Cape of Good Hope.

Coronida sinuosa Edmondson

Figs. 16, 17*a–e*

Coronida sinuosa Edmondson, 1921: 295, fig. 2.

DESCRIPTION: Carapace very slightly narrower anteriorly than posteriorly, nearly twice as long (including rostrum) as breadth at anterior border, lacking distinct carinae, cervical and gastric grooves wholly absent, anterolateral and posterolateral angles slightly rounded. Rostrum small, rounded anteriorly, breadth greater than length, not covering ophthalmic somite. Cornea of eyes set transversely on eyestalks, slightly bilobed; eyestalks narrow, elongated, flattened. Merus of raptorial claw articulating terminally with ischium (Fig. 17*b*), ventral surface longitudinally grooved throughout its length for reception of propodus; propodus finely pectinate along upper margin; dactylus notched and slightly inflated at base, with four sharp teeth on inner margin. First, third, fourth, and fifth thoracic appendages shown in Figure 17*a*, *c*, *d*. Mandibular palp absent. Free thoracic and abdominal somites dorsoventrally depressed, all lacking longitudinal carinae; fifth through eighth thoracic somites exposed, lateral margins of fifth with

an acute, anteriorly directed process, sixth, seventh, and eighth narrowed but evenly rounded (Fig. 16); dorsal surface of sixth abdominal somite ornamented with a scroll-like series of tubercles (carinae?), nearly symmetrical in arrangement. Telson with a series of similar tubercles which may be unsymmetrical except in the median region (Fig. 16); posterior border medially notched giving the appearance of two rounded lobes, with a pair of submedian spines and four to six marginal spines lateral to each submedian. Exopod of uropods with 8 to 11 movable spines on outer margin; elongated basal portion of uropods with two spines, inner longer than outer. First abdominal appendage of female shown in Figure 17*e*. Living animals are transparent white, preserved specimens opaque white throughout. Specimens range from 9.5 to 17.0 mm. in length.

DISCUSSION: Three female specimens of this small species have been examined, including the type specimen in the Bishop Museum. All had been collected from among dead coral on Waikiki Reef, Oahu.

The species is apparently closely allied to *Coronida multituberculata* (Borradaile) (1898), but differs considerably in the shape of the rostrum and in the ornamentation of the sixth abdominal somite and telson.

Specimens may be easily recognized by the ornamentation of the last two body segments. The tubercles (or carinae as they are called by Edmondson) of the sixth abdominal somite form a definite pattern which is nearly symmetrical on each side of the median line, suggesting a single median carina, paired submedian carinae, paired intermediate carinae, paired lateral carinae, and paired marginal carinae. The telson is similarly ornamented, but is not usually as symmetrical as shown in Figure 16. Here there is also a suggestion of a median carina, paired submedian carinae, and paired intermediate carinae; but all are somewhat joined to one another forming a scroll-like pattern. There appears to be considerable variation in the number of spines found on the posterior margin of the telson, and I am inclined to believe that there is but a single pair of submedian spines, the rest being small, marginal denticles, although Edmondson (1921) recognized two other pairs.

The slightly inflated base of the dactylus suggests affinities to *Gonodactylus* and *Odontodactylus*, but the articulation of the ischium and merus of the raptorial claw indicates a close relationship to *Squilla*, *Pseudosquilla*, and *Lysiosquilla*.

Because of their very small size it can be seen why this species has not been collected more often. The three specimens which I have examined ranged from 9.5 to 17.0 mm. from the tip of the rostrum to the distal end of the submedian spines of the telson. Living adults are also very transparent and difficult to see,

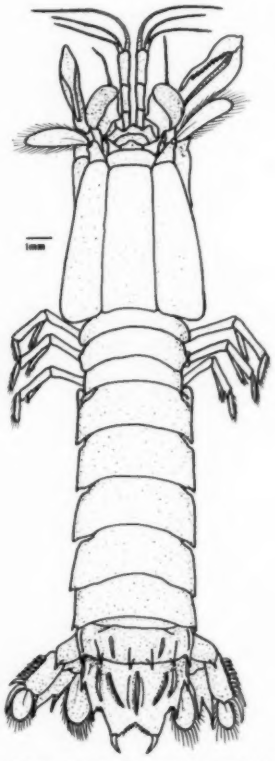

FIG. 18. *Odontodactylus hanseni* (Pocock) (male).

especially so in their native habitat on the reefs. Preserved specimens become opaque white or slightly yellowish, with the cornea of the eyes remaining very dark.

It is difficult to say whether or not the specimens are mature and whether there is a distinct sexual dimorphism, because all specimens are females and none were ever collected with egg masses. The absence of the gastric grooves and the very elongated antennal somites suggests that possibly they are in an immature stage. Edmondson (1921) states that the specimen in the Bishop Museum was kept alive for a month, during which time it molted with no apparent increase in size or change in structure.

DISTRIBUTION: All specimens collected have come from dead coral heads on Waikiki Reef, Oahu.

Odontodactylus hanseni (Pocock)

Figs. 18, 19*a–f*

Gonodactylus hansenii Pocock, 1893: 477, pl. 20, figs. 3, 36.

Odontodactylus latirostris Borradaile, 1907: 212, pl. 22, figs. 3, 3a.

DESCRIPTION: Carapace longer than greatest breadth, slightly narrower anteriorly than posteriorly, with distinct gastric grooves, cervical groove wholly absent, longitudinal carinae lacking, anterolateral and posterolateral angles unarmed and rounded. Anterior margin of rostrum evenly rounded, twice as broad as long. Ophthalmic somite exposed, dorsal process deeply excavate anteriorly. Eyes large, globular, corneal diameter 0.25 to 0.5 the length of carapace, excluding rostrum (Fig. 18). Ischio-meral articulation of raptorial claw situated at a point in advance of proximal end of merus (Fig. 19*b*); ventral surface of merus grooved longitudinally for not more than 0.6 its length for reception of propodus; upper surface of propodus not pectinate; dactylus inflated at base, armed with 9–11 teeth on its inner margin. Propodus of third, fourth, and

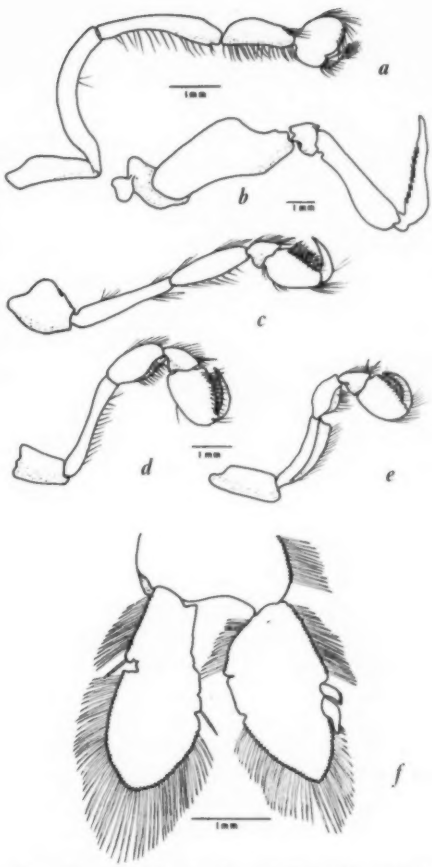

FIG. 19. *Odontodactylus hanseni* (Pocock). *a,b,c,d,e*, Right first, second, third, fourth, fifth thoracic appendages; *f*, right first abdominal appendage of male.

fifth thoracic appendages somewhat shield-shaped (Fig. 19*c–e*). Mandibular palp of three segments. Free thoracic and abdominal somites laterally compressed, distinct longitudinal carinae present only on sixth abdominal somite; sixth, seventh, and eighth thoracic somites exposed, lateral borders rounded; posterolateral angles of fourth and fifth abdominal somites ending in a short acute spine; sixth abdominal somite with four pairs of longitudinal carinae, one submedian pair ending in spines, one intermediate pair without spines, one second lateral pair ending in spines, one

marginal pair ending in spines. Telson with high median carina ending in a short terminal spine, submedian, intermediate, second lateral, and marginal carinae; armed with three pairs of strong marginal teeth, submedian (with movable tips), intermediate, and lateral; no submedian denticles but a series of minute spinules, two intermediate denticles, and a single lateral denticle. Exopod of uropods with 10 or 11 movable spines on outer margin. Basal portion of uropods elongated into two spines, inner shorter than outer. First abdominal appendage of male shown in Figure 19*f*. Color of the specimens is a uniform light yellowish pink above with the exposed thoracic and first four abdominal somites having a light pink posterior margin. The large globular eyes are dark brown and the flagella of the antennae are pink. The animals are quite small with the reported range in length from 27 to 80 mm.

DISCUSSION: In dorsal aspect this species very closely resembles small specimens of *Psuedosquilla*, but the ischio-meral articulation of the raptorial claw and the large globular eyes are suitable for distinguishing members of this genus from those of *Pseudosquilla*. The inflated dactylus and the ischio-meral articulation of the raptorial claw are features which members of this genus have in common with *Gonodactylus*, but the numerous carinae on the telson, the nonpectinate upper margin of the raptorial propodus, and the series of teeth on the inner margin of the raptorial dactylus will serve to separate this group from the latter. As stated by Bigelow (1894) this genus seems to occupy an intermediate position between *Gonodactylus* and *Pseudosquilla*.

Five female and three male specimens of this species have been examined, all of which were taken from stomachs of the skipjack, *Katsuwonus pelamis*, and of the yellowfin tuna, *Neothunnus macropterus*. The Bishop Museum has one male and two females which were dredged off Waikiki, Oahu, at a depth ranging from 30 to 50 fathoms. Pocock's (1893) type specimen was a single female from the Macclesfield Bank, South China Sea, at a depth of 35 fathoms. Bigelow (1931) reported four males, one female, and two juveniles taken in Hawaiian waters by the "Albatross" in 1902 at depths ranging from 24 to 83 fathoms. The specimens which I have examined are in agreement with those previously reported. Some characteristics were relatively difficult to distinguish, but I attribute this to the fact that the animals were considerably disfigured from having been in the stomach. Edmondson (1921) has illustrated the telson of this species more clearly than is shown in Figure 18.

There appears to be no distinct sexual dimorphism. The first abdominal appendage of the male shown in Figure 19*f* is incomplete because the fixed limb in all three specimens was indistinguishable.

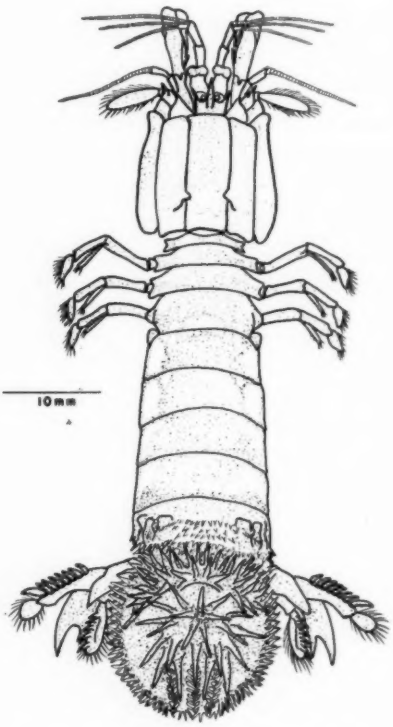

FIG. 20. *Gonodactylus guerini* White (female).

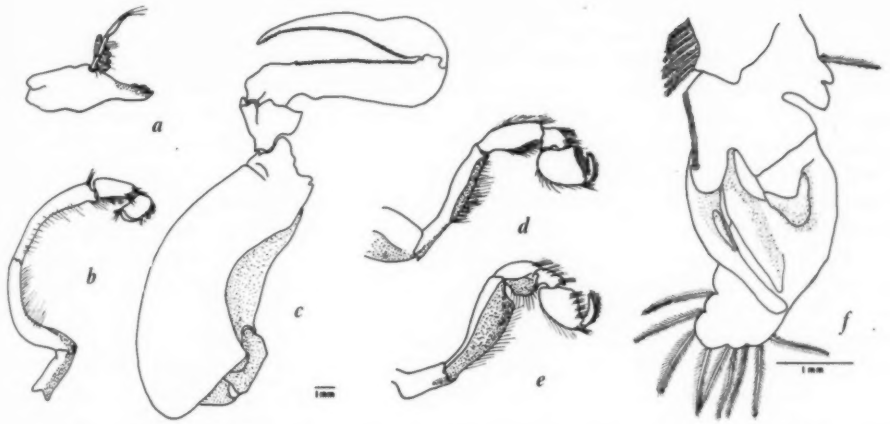

FIG. 21. *Gonodactylus guerini* White. *a*, Right pars molaris of mandible and mandibular palp; *b*, *c*, right first and second thoracic appendages; *d*, right third and fourth thoracic appendages; *e*, right fifth thoracic appendage; *f*, left first abdominal appendage of male (endopod only).

Evidently this species is quite common in deeper water because all other specimens have been taken at considerable depths. Apparently this species forms a considerable part of the diet of the tunas, inasmuch as the adults and larvae are often found in stomach contents. This indicates that this species is probably semiplanktonic, because the tunas feed in mid-water or at the surface. These stomatopods certainly spend some time on the bottom because other specimens have been dredged from a rough substrate.

DISTRIBUTION: Specimens have been reported from the Hawaiian Islands, the South China Sea, the East Indian Archipelago, and the Indian Ocean.

Gonodactylus guerini White

Figs. 20, 21*a–f*

Gonodactylus guerinii White, 1861*a:* 43, pl. 7; 1861*b:* 480.

Protosquilla guerinii Brooks, 1886: 75, pl. 16, figs. 1, 6.

DESCRIPTION: Carapace rectangular, nearly as wide as long, slightly narrower anteriorly, anterolateral and posterolateral angles broadly rounded, lacking distinct carinae, gastric grooves well defined, cervical almost obsolete. Rostrum quadrate, trispinous, covering ophthalmic somite. Eyes small, tubular; cornea bilobed, set transversely on stalk. Ischiomeral articulation of raptorial claw situated at a point in advance of proximal end of merus so that merus extends backward beyond the joint (Fig. 21*c*); ventral surface of merus longitudinally grooved for not more than 0.75 its entire length for reception of propodus; upper margin of propodus with a series of fine acute teeth; dactylus inflated at base, elongated into a single acute tooth, inner margin of dactylus serrated. First, third, fourth, and fifth thoracic appendages shown in Figure 21*b*, *d*, *e*. Mandibular palp present, three segments (Fig. 21*a*). Free thoracic and abdominal somites laterally compressed, all lacking longitudinal carinae (indication of slight marginal carinae on first five abdominal somites); fifth through eighth thoracic somites exposed, slightly narrower than posterior width of carapace; posterior portion of fifth abdominal somite bears several rows of short spines, separated from smooth anterior part by a curved transverse line; sixth abdominal

somite armed with numerous long spines, each ending in a blunt, rounded tip from which protrudes a soft fleshy process. Articulation between telson and preceding segment barely discernible dorsally. Telson covered with series of 22 regularly arranged spines similar to those of preceding segment; distal margin composed of four spine-like processes bearing secondary spines on outer edges, two submedian with single row of secondary spines, two intermediate with single inner row of secondary spines and double row of secondary spines along outer border (Fig. 20). Exopod of uropods with eight movable spines on outer margin; endopod with five spines on dorsal surface; elongated basal portion of uropods with two spines, outer longer than the inner. Endopod of first abdominal appendage of male shown in Figure 21*f*. Specimens, when alive, are a brilliant red or orange. Specimens preserved in alcohol immediately turn a mottled yellow or tan, but those preserved in formaldehyde have retained their red color after several months. Specimens range in size from 28.5 to nearly 70 mm. from the tip of the rostrum to the distal margin of the telson.

DISCUSSION: This is the only species of this world-wide genus which has been reported from the Hawaiian Islands. The type specimen was taken by H.M.S. "Herald" at Fiji Islands. Miers (1880) reported this to be a female, but Kemp (1913) stated that it was a male; apparently Kemp was the one who made the error in identification. Another female was taken at Honolulu by H.M.S. "Challenger," but Brooks (1886) put it in the genus *Protosquilla*. The only other record of the species is a single male specimen in the Bishop Museum which was taken off Waikiki, Oahu. In the spring of 1949 two males and four females were dredged off Waianae, Oahu, in water 50–120 fathoms deep. This appears to be the greatest number of specimens collected at any one time.

This species is easily recognized by the radiating series of spines found on the telson and the last two abdominal somites. The rectangular carapace with its trispinous rostrum is found in several species of this genus.

Gonodactylus and its related genus, *Odontodactylus*, are very similar with regard to the ischiomeral articulation and the inflated base of the raptorial dactylus (Fig. 21*c*); however, *Gonodactylus* is distinguished by the absence of spines on the raptorial dactylus, which may be entirely smooth or serrated on its inner margin (Fig. 21*c*). *Odontodactylus*, on the other hand, has several spines on the inner margin of the raptorial dactylus.

Brooks (1886) placed this and several allied species in a new genus, *Protosquilla*, because the telson and sixth abdominal somite, although separate, were nearly fused. He also stated that the small size of the antennary scales and uropods and the trispinous rostrum were sufficiently distinct to warrant the removal of these species from the genus *Gonodactylus*. Kemp (1913) and Edmondson (1921), however, did not consider these differences of a generic nature and retained the original name applied to the species by White (1861).

Two specimens were kept alive for observation in an aquarium. Both were females, one of which was collected with a mass of fertilized eggs; the other laid a mass of eggs in captivity. Both specimens survived very well even though they were both dredged from a depth of over 100 fathoms. The fertilized eggs developed until the time of hatching but then began to degenerate. Several eggs from the mass were removed at intervals and preserved in 7 per cent formalin solution with the hope that eventually they might be used to describe the embryology of this species. One female molted once while in captivity and remained a mottled yellow afterward. Little has been written about the function of the elaborate spines on the telson; however, my observations have shown that the animals either burrow into the substrate or select holes in dead coral which are just large enough for them to crawl into. Ordinarily they are found partially emerged from their burrows but when

disturbed they turn around and close the opening with their telson, which thus serves as an effective protective mechanism.

DISTRIBUTION: This species has been reported from Fiji and Honolulu, from relatively deep water, the only record being 50–120 fathoms.

LARVAL HAWAIIAN SQUILLIDAE

Larval stomatopods form a considerable part of the neritic plankton throughout the warmer waters of the world. They are transparent organisms which, at hatching, have many adult characteristics; however, the diagnostic features of the adult do not appear until late in development, thus making it difficult to associate the larval forms with the proper adults. The first attempt to draw up a key to the larvae was made by Bigelow (1894); however, he based his key on the general appearance of the forms, a characteristic which is often very deceptive. Hansen (1895) made a careful study of the larvae and divided them into two major groups, the alima-type larvae of *Squilla* and the erichthus-type larvae of *Lysiosquilla*, *Coronida*, *Odontodactylus*, *Gonodactylus*, and *Pseudosquilla*, on the basis of the shape of the propodus of the third, fourth, and fifth thoracic appendages. This division was thought by Hansen to emphasize the relationship of the various genera to one another, but Kemp (1913) and Foxon (1932) do not believe that this is of phylogenetic importance, because none of the larval types possesses characteristics which can be considered as an ancestral condition from which the rest of the genera developed.

Giesbrecht (1910) has noted that in the Stomatopoda two types of larvae occur at hatching, but the differences between them gradually disappear through a succession of later stages. These two early larval types have been designated pseudozoea and antizoea. The antizoea is characterized at the time of hatching by biramous appendages on the first five thoracic somites, an abdomen which is usually unsegmented and lacking pleopods, and by later development into an erichthus type of larva. The pseudozoea hatches with only the first and second thoracic appendages, the second being in the form of a raptorial claw as in the adult, a fully segmented abdomen bearing four pairs of functional pleopods; later these develop into either an erichthus- or an alima-type of larva. Species of *Lysiosquilla* and *Coronida* hatch as antizoea, later developing into erichthus larvae; species of *Gonodactylus*, *Odontodactylus*, and *Pseudosquilla* all hatch as pseudozoea and later develop as erichthus larvae. Species of *Squilla* hatch as pseudozoea but later develop an alima-type of larva.

Foxon (1932), following the work begun by Hansen, attempted to bring the classification of the larvae into agreement with the divisions of the adults as presented by Kemp (1913). In doing this he has set down the morphological features which serve to identify the larvae from their earliest stages until the time they take on the characters observed in the adults. Brooks (1886), Giesbrecht (1910), Hansen (1926), and Foxon (1932) have all noted that the only constant difference between alima and erichthus larvae is the number of intermediate denticles between the submedian and the two lateral denticles of the telson. In the former there are always more than four of these denticles, whereas in the latter there are less than four. If one uses these denticles as a diagnostic character, it is then possible to divide the larval forms into the same major groups as the adults. In using this system of classification the larval groups are the same as those of the adults, the likeness becoming greater at each successive molt.

This method of classification is unquestionably suitable for distinguishing the genera to which the larvae belong, but it is a much more difficult task to assign them to their proper species. In no species has an individual in an early larval stage been reared to the adult form. Individuals in later stages have been reared to the postlarval condition, but they are so delicate that laboratory con-

ditions must be ideal, requiring water which is well aerated and free of sediment. In consequence, I have found it necessary to assign the larval species on the basis of the adult characteristics. If one has identified all adult species occurring in a particular region, then, by studying the postlarval forms which show both adult and larval characteristics, it is possible to correlate the larval forms occurring in the same region by working back from the adult species to the earliest recognizable larvae of those species. Using this method, I have been able to identify larval stages of *Pseudosquilla* as those belonging to adult *P. ciliata*. Larvae of *Lysiosquilla* and *Squilla* are likewise assigned to their respective species, but this identification is not positive. At this time larvae of *Coronida* and *Odontodactylus* cannot be referred to any definite species. Larval forms of *Gonodactylus* have not been found in these waters.

The following key is designed to facilitate the identification of the larvae with their respective genera, and is intended to be used for larvae in all stages of development. There is no reference to species, but where the adult species is known it will be mentioned in the description given for each genus.

Key to the Genera of Larval Hawaiian Stomatopoda

A. Larvae hatch without raptorial claw (antizoea with biramous appendages on first 5 thoracic somites) or with raptorial claw (pseudozoea with only first and second thoracic appendages) and with the propodus finely pectinate along its upper margin; ischio-meral articulation of raptorial claw always terminal in later stages (Figs. 22*a*, 25*b*) . . . . . **B**

AA. Larvae always hatch with raptorial claw (pseudozoea) and the propodus never pectinate along its upper margin; ischio-meral articulation of raptorial claw at a point in advance of the proximal end of the merus in later stages (Fig. 28*a*) . . **E**

B. Larvae hatch with raptorial claw (Fig. 22*a*); propodus of fourth thoracic appendage rectangular, generally longer than broad, and only slightly broader than that of fifth (Fig. 23*f*) . . . . . **C**

BB. Larvae hatch with biramous thoracic appendages (Fig. 25*a*) which undergo transformation into typical subchelate form; propodus of fourth thoracic appendage rounded, broader than long, more than twice as large as that of fifth (Fig. 27*b*) . . . . . **D**

C. Telson with 4 or more intermediate denticles between submedian and lateral denticles (Fig. 22*b*) . . . . . *Squilla* (alima larva)

CC. Telson with 3 or fewer intermediate denticles between submedian and lateral denticles (Fig. 23*e*) . . . . . *Pseudosquilla* (pseuderichthus larva)

D. Propodus of raptorial claw broad, dactylus slightly inflated at base (Fig. 26*e*) . . . . . *Coronida* (coroniderichthus larva)

DD. Propodus of raptorial claw long and slender, dactylus not inflated at base (Fig. 25*b*) . . . . . *Lysiosquilla* (lysioerichthus larva)

E. Spines of telson greatly elongated (Fig. 28*a*) . . . . . *Odontodactylus* (odonterichthus larva)

EE. Spines of telson not greatly elongated . . . . . *Gonodactylus* (gonerichthus larva)

Squilla sp?, probably **S. oratoria**

Fig. 22*a–d*

STAGE 1 (Fig. 22*a*): This is the earliest stage of the alima-type larva which has been found. Larvae bear completely developed first and second thoracic appendages, the second being in the form of a raptorial claw; propodus of this claw with two small spines near its proximal end, upper margin finely pectinate; dactylus nearly straight, no teeth along inner margin; eyes borne on long stalks, this condition being retained throughout successive stages; antennules fully formed; antennal

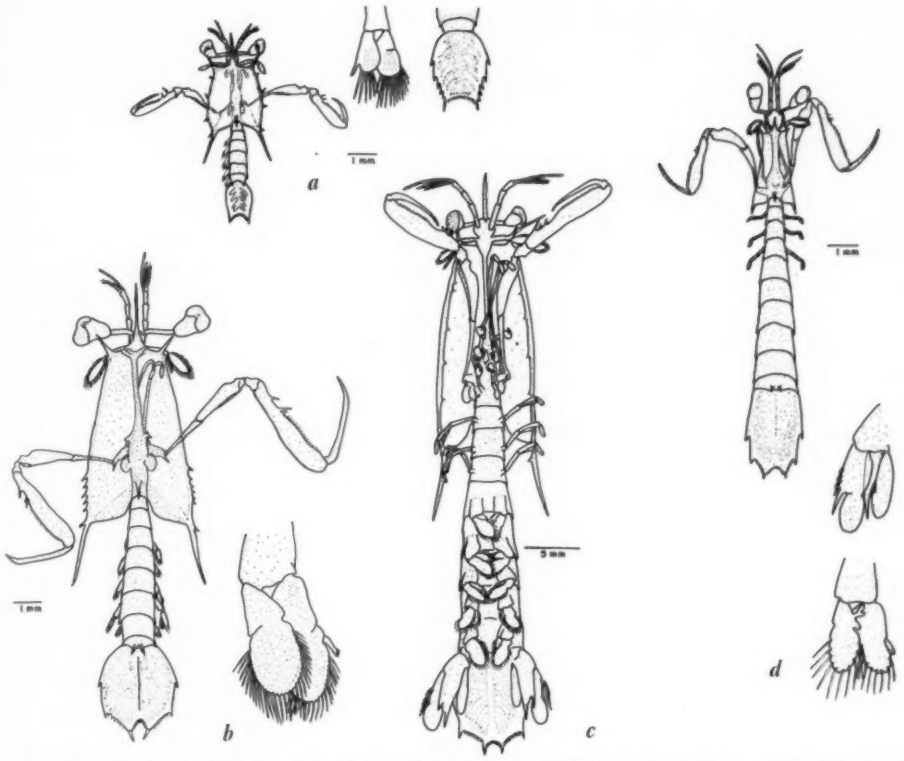

FIG. 22. Larval forms of *Squilla*. *a*, Dorsal view of pseudozoea, first abdominal appendage and telson (probably *S. oratoria*); *b*, dorsal aspect of alima larva and first abdominal appendage (probably *S. oratoria*); *c*, ventral aspect of alima larva (probably *S. oratoria*); *d*, dorsal aspect of alima larva, first abdominal appendage and uropod (*Squilla* sp.).

scale present but flagella absent; carapace very clear, covering nearly 0.5 the entire body, this relationship remaining the same throughout successive stages; anterior margin of carapace trispinous, posterior margin with two posterolateral spines and small zoeal spine between them; lateral margins of carapace usually armed with three laterally directed and two ventrally directed denticles, small denticle at base of posterolateral spines; abdomen completely segmented, sixth abdominal somite indistinct; four pairs of biramous pleopods without gills, fifth pair represented by small buds; no uropods; telson longer than wide with 11 or 12 denticles between submedian denticles and four between lateral and submedian denticles.

The specimens range in size from 5.5 to 8.0 mm. from the tip of the rostral spine to the posterior margin of the telson. This stage has been taken in plankton tows in the waters around Oahu throughout the year, most abundantly during the summer months.

STAGE 2 (Fig. 22*b*): This larval form is similar to the preceding stage except for a conspicuous change in size, the animals now measuring 15 to 20 mm. Body proportions remain the same, carapace still covering nearly 0.5 total length of body; antennal flagella present; third, fourth, and fifth thoracic ap-

pendages present; sixth, seventh, and eighth thoracic appendages represented by small buds; abdominal appendages all present, with small gills attached to exopods; uropods beginning to form; sixth abdominal somite with two small submedian spines; telson well developed, beginning to assume adult condition with two well-developed spines on distal margin and distinct submedian and intermediate denticles.

As with the first stage, all the specimens have been collected from regions where *S. oratoria* is either known or thought to be present. Innumerable specimens have been taken in plankton tows in the waters around Oahu throughout the year. They may frequently be found in the stomach contents of the yellowfin tuna, *Neothunnus macropterus*.

STAGE 3 (Fig. 22*c*): By the time the larvae have reached this stage, they have gained further adult characteristics. Sixth, seventh, and eighth thoracic appendages fully developed; uropods with adult characteristics, basal portion elongated into two spines and small rounded lobe between them, exopods with eight spines, as yet immovable, along their outer margin; telson more adult-like in appearance; no longitudinal carinae on body; carapace still very transparent, no indication of facies of adult carapace showing through chitin.

At this time the specimens measure 45 to 60 mm. in length. This stage forms a conspicuous part of the plankton and has been taken in plankton tows from the surface down to a depth of 200 meters.

There are no specimens beyond this stage in the collections. It is rather unusual that no postlarval forms have been found in which the adult characteristics such as the body carinae, the adult carapace, and the teeth on the raptorial dactylus are present. I assume from this that the larvae become bottom dwellers immediately after they lose the larval carapace.

Squilla sp?

Fig. 22*d*

Approximately 200 specimens of this alima larval stage were taken in night light stations at Honolulu Yacht Harbor, Oahu. They closely resemble the preceding larval types, but, as only one stage was collected, it is impossible to assign the specimens to an adult species. Carapace covers less than 0.3 total length of body, very narrow; all appendages fully developed, gills represented by small buds on exopod of pleopods; telson very large compared with other body segments, composing about 0.25 total length of body; fully developed uropods, bearing five spines along outer margin of exopod, with basal portion elongated into two spines, inner shorter than outer.

Pseudosquilla ciliata

Figs. 23*a–f*, 24*a–c*

STAGE 1 (Fig. 23*a*): Brooks (1886) has illustrated a pseudozoea larva similar to this stage. This represents the earliest larval stage of members of the genus *Pseudosquilla*. By observing the relative changes in the other stages, I have come to the conclusion that these are the young of *P. ciliata*. Typical erichthus larva with only first and second thoracic appendages present; abdomen with four pairs of biramous pleopods, without gills; telson nearly rectangular, with eight small denticles between submedian denticles; eyes not borne on long stalks as in alima of *Squilla* as articulation is close to ophthalmic somite; antennules present; antennae appear as small buds; merus and ischium of raptorial claw with terminal articulation, propodus finely pectinate along upper margin, dactylus composed of single spine; carapace trispinous anteriorly, posteriorly bearing two long spines reaching second abdominal somite; may or may not have small zoeal spine between two posterior spines; carapace longer than broad, its lateral margins depressed.

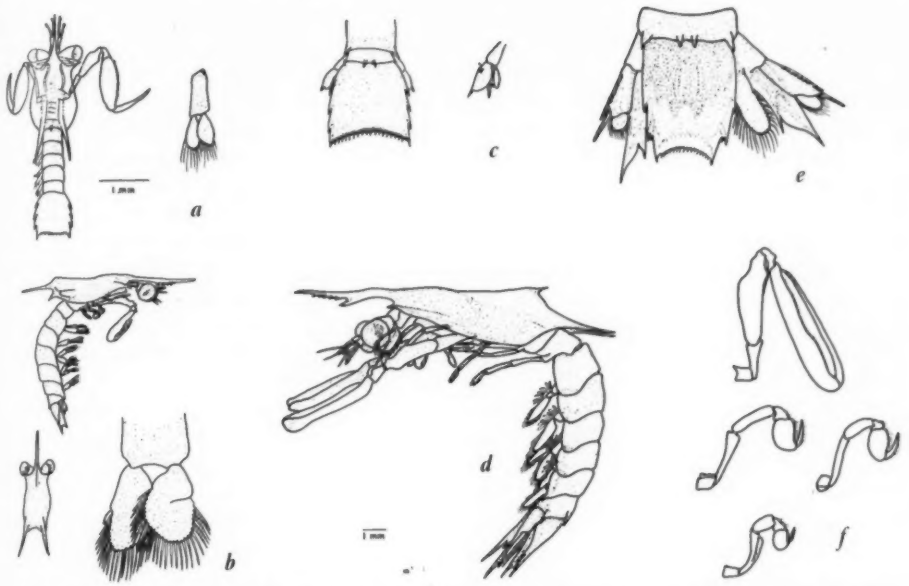

FIG. 23. Larval forms of *Pseudosquilla ciliata* (Fabricius). *a*, Dorsal aspect of pseudozoea and first abdominal appendage; *b*, lateral aspect of pseuderichthus larva, dorsal aspect of carapace and first abdominal appendage; *c*, dorsal aspect of last abdominal somite, telson, and uropods of larva shown in *b; d*, *e*, lateral aspect of larger pseuderichthus larva and dorsal aspect of last abdominal somite, telson, and uropods; *f*, second, third, fourth, and fifth thoracic appendages of larva *d*.

Larval specimens in this stage of development have been taken in great numbers in plankton tows throughout the year at Kaneohe Bay, Oahu. Since adults of *P. ciliata* and *oculata* occur in abundance on the reefs in the bay, these specimens are believed to be the first larval stage of a *Pseudosquilla*. Unfortunately, I find no way to differentiate the early larvae of species in this genus. The specimens vary from 3.5 to 5.0 mm. from the tip of the rostral spine to the posterior margin of the telson.

STAGE 2 (Fig. 23*b*, *c*): At this stage in development the larvae show characteristics of both the preceding stage and the fourth stage. Entire body and larval carapace have increased in size but retain same relative proportions to one another; carapace may or may not bear small zoeal spine; first through fifth thoracic appendages present; propodus of fourth and fifth thoracic appendages rectangular in shape and nearly equal in size (not well shown in Fig. 23*b*); no appendages on sixth through eighth thoracic somites; eyes globular, protruding from anterior margin of carapace; antennae present; pleopods resemble those of following stage, but have no gills; sixth abdominal somite distinct, bearing two submedian spines; uropods composed of short exopod and endopod, with basal portion elongated into two spines, inner shorter than outer; telson retains same general appearance of preceding stage, but somewhat larger.

Specimens measure 9.5 to 12.5 mm. in length. Approximately 200 individuals in this stage of development have been examined. Most of the specimens were taken in plankton tows from Kaneohe Bay, Oahu, but they have also been found in the tows from the Molokai Channel made by the Territorial Division of Fish and Game.

STAGE 3: This stage has not been found, but examination of the preceding stage and that of the next indicates what specimens in this stage of development should look like. By this time, all appendages should be present, gills should appear on the exopod of the pleopods, and the telson and uropods should be similar to the following stage. They should range from 15 to 20 mm. in length.

STAGE 4 (Fig. 23*d–f*): Thoracic appendages all present, showing adult characteristics, except raptorial claw; raptorial claw still very long and slender, propodus much longer than ischium and merus combined, dactylus composed of a single long spine with no indication of teeth along inner margin; facies of postlarval carapace and rostrum show through chitin of larval carapace; uropods greatly enlarged with two immovable spines on outer margin of exopod, definite pits for others show through chitin, outer spine of basal prolongation of uropods longer than innner; telson armed with two submedian, two intermediate, and two lateral spines, with 15 to 20 denticles between submedian and intermediate spine; facies of postlarval telson showing through chitin, with characteristic shape of adult, being nearly as broad as long.

Specimens of this stage measure 20 to 22.5 mm. in length. Very few of these larvae have been collected in regions where the previous stages were most numerous. Occasionally they are taken in the protected inshore waters, but they are more often found in the offshore waters such as the Molokai Channel. This seems to indicate that these larvae seek less sheltered waters and return to the shallow inshore waters only when they lose the larval carapace.

STAGE 5: There are no great changes from the preceding stage at this time. Slight increase in size; carapace very loosely attached to body; mandibular palp present, composed of three segments; nine or ten immovable spines along outer margin of exopod of uropod.

STAGE 6 (Fig. 24*a*, *b*): This is the first postlarval form of *P. ciliata*. No larval carapace, but animals remain planktonic; eyes resemble adult, nearly tubular in shape, cornea following long axis of stalk; rostrum triangular; carapace distinctly adult in shape, with distinct gastric grooves, covering only anterior 0.25 of body; all appendages, except second thoracic appendage, resemble those of adult; second thoracic appendage, raptorial claw, with shortened propodus and dactylus so that they fit into grooved merus and ischium when flexed, dactylus still lacks teeth on inner

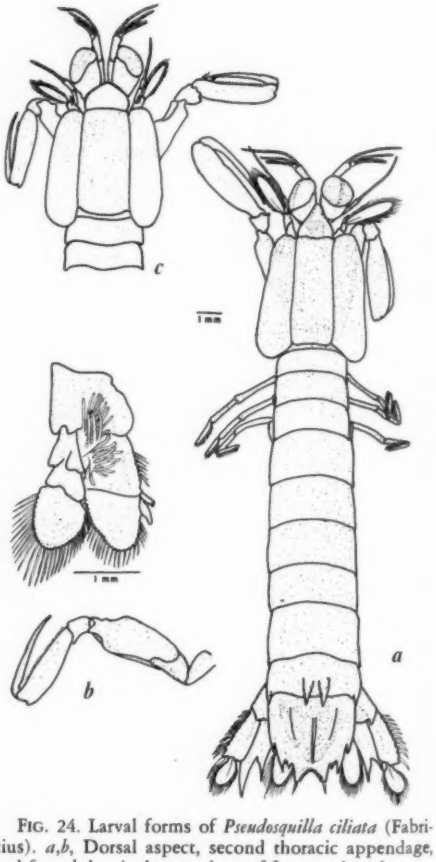

FIG. 24. Larval forms of *Pseudosquilla ciliata* (Fabricius). *a,b*, Dorsal aspect, second thoracic appendage, and first abdominal appendage of first postlarval stage; *c*, dorsal aspect of anterior segments of last postlarval stage.

margin; abdominal somites and appendages distinctly adult in structure, gills on pleopods nearly fully developed, sixth abdominal somite with two well-developed submedian and two lateral spines; uropods with nine or ten movable spines along outer margin of exopod, spines of elongated basal portion changing relationship to one another so that in some specimens these two spines are nearly equal in length; telson with three distinct longitudinal carinae, median and two submedians, posterior margin with pair of movable submedian spines bearing series of denticles between them, pair of immovable intermediate spines with two denticles between them and submedian spines, pair of immovable lateral spines.

The specimens now reach a maximum length of 20 to 25 mm. This developmental stage is very common in the plankton during the spring and summer months and occurs in both the inshore and offshore waters of Hawaii. They may occasionally be found in the stomach contents of the yellowfin tuna, *Neothunnus macropterus*, and the skipjack, *Katsuwonus pelamis*.

STAGE 7 (Fig. 24*c*): There is little change in this form from the preceding stage. Rostrum nearly adult in form, broader than long; eyes more tubular in shape; raptorial dactylus composed of single tooth, facies of other teeth on inner margin can be seen through chitin in some specimens.

Individuals in this developmental stage have been taken in the plankton from Kaneohe Bay, Oahu, and at Honolulu Yacht Harbor, Oahu. This indicates that the larvae are returning to the shallower, more protected waters and are preparing to settle down on the bottom to complete their life cycle.

Lysiosquilla sp?

Fig. 25*a*

Brooks (1886) has illustrated this antizoeal form and states that numerous specimens were taken by the "Challenger" at Honolulu. Both Brooks's specimens and those at hand agree with those described by Claus (1872) from Messina. These very small larvae occur in great numbers in the plankton throughout the year. Due to their relatively small size (2.5 to 3.5 mm.) they are very often overlooked or cast aside as some unknown form. Although they lack the characteristic subchelate appendages, the eyes and telson have distinct stomatopod characteristics. These larvae represent the first larval stage of *Lysiosquilla* or *Coronida*, and because of their great abundance I am inclined to believe that they belong to *Lysiosquilla* which is apparently more abundant in Hawaiian waters than *Coronida*. There is no diagnostic character sufficiently developed to indicate conclusively the species to which these specimens belong, and none have ever been reared in captivity to the following stage. The carapace completely covers the animal from head to abdomen leaving only the eyes and telson exposed. There are five pairs of biramous thoracic appendages present, the abdomen is only faintly segmented, and the pleopods are absent. This larval form gives rise to an erichthus in later stages.

Lysiosquilla sp?

Figs. 25*b*, *c*

Nine specimens of this lysioerichthus stage were collected in a plankton tow in the Molokai Channel. In all respects this larval form represents the typical lysioerichthus. No spines between submedian and lateral spines on telson (Fig. 25*c*); raptorial propodus finely pectinate along upper margin, dactylus composed of single acute spine, not inflated at base, ischio-meral articulation terminal; all thoracic appendages present, propodus of third and fourth rounded and broader than long, fourth nearly twice as large as that of fifth; abdomen increasing in breadth posteriorly; pleopods all present, gills absent; uropods partially developed, exopod and endopod both present, with basal portion elongated into two spines,

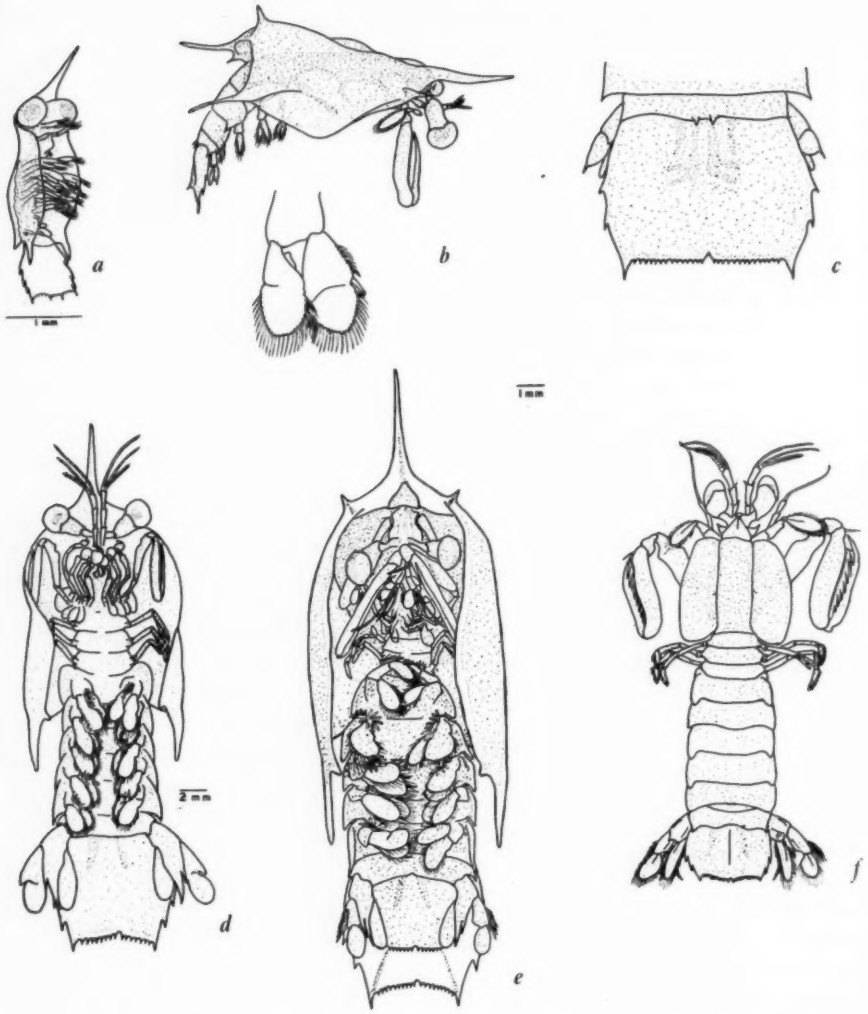

FIG. 25. Larval forms of *Lysiosquilla*. *a*, Antizoea; *b*, lateral aspect of lysioerichthus larva and first abdominal appendage; *c*, dorsal aspect of last abdominal somite, telson, and uropods of same; *d*, ventral aspect of lysioerichthus larva; *e*, ventral aspect of last larval stage of *L. maculata; f*, dorsal aspect of first postlarval stage of *L. maculata*.

inner longer than outer; carapace nearly as broad as long from base of anterolateral spines to base of posterolateral spines, lateral margins turned downward and toward median line; most preserved specimens with abdomen and telson reflexed anteriorly so that ventral opening of carapace is completely closed.

Specimens measure 14.5 to 28.5 mm. in length. The 28.5 mm. specimen shows the facies of ten spines along the inner margin of the raptorial dactylus much the same as those seen in the adults of *L. maculata*.

Lysiosquilla sp?

Fig. 25*d*

This lysioerichthus larval form is represented by a single specimen taken in a plankton tow in the Molokai Channel. Its very large size (45 mm.) immediately draws attention. All structures are the same as for the previously described larvae of this genus. It was temporarily believed to belong to *L. maculata*, but its size and relative immaturity (cf. Fig. 25*e*, which is only 15 mm. long) seem to indicate that it may be the larval stage of a species of *Lysiosquilla* which has not been found in the adult form in Hawaii.

Lysiosquilla maculata

Fig. 25*e*, *f*

Figure 25*e* represents one of seven lysioerichthus larvae, three of which were collected in plankton tows at Truk Island and four from Kawaihae, Hawaii. These are fully developed larvae, which I believe to be the last larval stage of *L. maculata*. This conclusion is based on an examination of postlarval forms and the adults of this species. Appendages, except raptorial claw, telson, and uropods, resemble those of adult *L. maculata;* facies of postlarval telson show through chitin, very closely resembling telson of postlarval forms shown in Figure 25*f*. It is very probable from these facts that the next molt would produce the postlarval stage of *L. maculata*. Specimens range from 15 to 16 mm. from the tip of the rostral spine to the posterior margin of the telson.

The postlarval form (Fig. 25*f*) undoubtedly belongs to *L. maculata*. All anterior appendages are the same as those of the adult, and the raptorial dactylus bears nine teeth on its inner margin similar to the condition found in some of the adults of this species. The telson and uropods have the same general appearance of the adult as well. These specimens and the adults have eight spines along the outer margin of the exopod of the uropods. A single specimen measuring 16.5 mm. in length was collected at Kawaihae, Hawaii, at a night light station, which further substantiates the identification because the adult species is very common in that region.

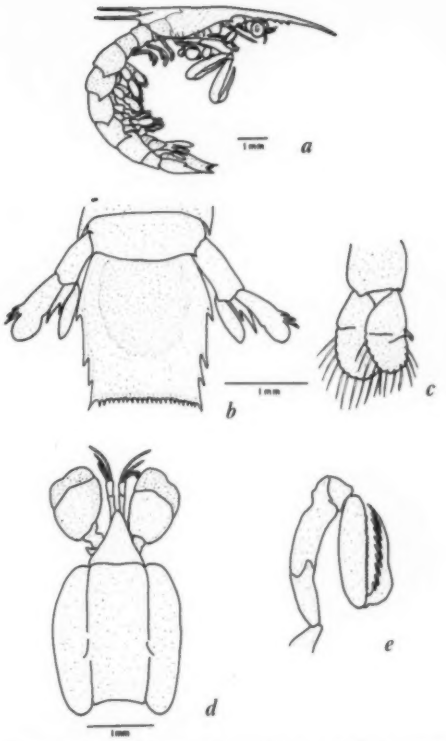

FIG. 26. Larval forms of *Coronida* sp. *a*, Lateral aspect of last larval stage of coronideriehthus larva; *b*, dorsal aspect of last abdominal somite, telson, and uropods of same; *c*, first abdominal appendage of same; *d*, dorsal aspect of anterior segments of first postlarval stage; *e*, second thoracic appendage of same.

Coronida sp?

Fig. 26*a–e*

In Figure 26*a* there is represented the last larval stage (coronideriehthus) of some unknown species of *Coronida*. This form is found in the Ala Wai Canal, Oahu, and at Kawaihae, Hawaii, in moderate numbers dur-

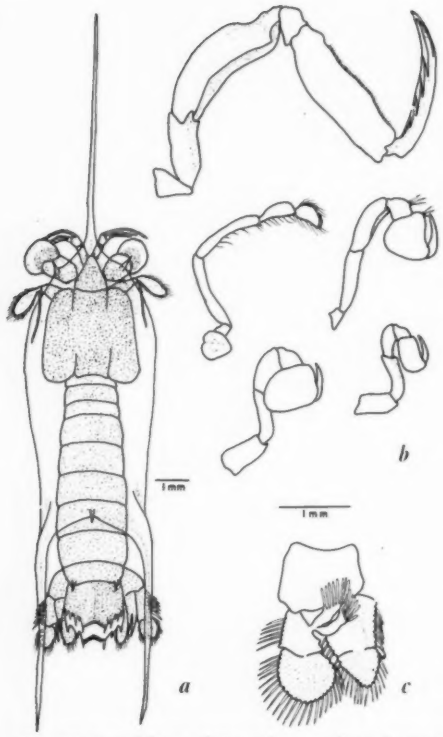

FIG. 27. Larval form of *Coronida* sp. *a*, Dorsal aspect of coronideriehthus larva; *b*, second, first, third, fourth, and fifth thoracic appendages; *c*, first abdominal appendage.

ing the summer. Larvae resemble lysioerichthus in shape of thoracic appendages, but with raptorial dactylus slightly inflated at its base; propodus of fourth thoracic appendage rounded, nearly twice as large as that of fifth which is rectangular; all abdominal appendages present; no gills; telson rectangular as in most larval forms, bearing two denticles between submedian and lateral denticles; uropods present, outer margin of exopod armed with three spines, basal portion elongated into two spines, outer longer than inner.

Specimens measure 10.0 to 14.5 mm. from the tip of the rostral spine to the posterior margin of the telson.

Figures 26*d*, *e* represent the first postlarval stage of this species which is found in nearly equal numbers with the previous stage. Only the carapace and anterior segments and the raptorial claw have been illustrated as all other structures are the same as those seen in the preceding stage. The inner margin of the dactylus is armed with ten teeth. There is no distinct increase in size over that of the last larval stage. These forms may be larval stages of *C. sinuosa*, but the larval structures bear no resemblance to diagnostic characteristics of this species. Apparently the species to which these larvae belong is quite common, although it has not been found as yet.

Coronida sp?

Fig. 27*a–c*

Five coronideriehthus larvae measuring 18 to 20 mm. from the tip of the rostral spine to the posterior margin of the telson were collected at Kawaihae, Hawaii. The appendages indicate that they belong to some species of *Coronida*, but no adult specimens have been found which have the same characteristics as those possessed by this larval stage. I believe that the first postlarval stage would appear at the next molt because the facies of the adult carapace, telson, and raptorial dactylus show through the very clear chitin. These specimens are unique in that the larval carapace covers all but the last two abdominal somites and the telson, and the median anterior spine and posterolateral spines are greatly elongated. This condition is not found in any other larval form, hence it should serve as a diagnostic character for the separation of this larval form from others belonging to this genus.

Odontodactylus sp?

Fig. 28*a–e*

Eight odonterichthus larvae, ranging in length from 18 to 35 mm., were taken in a plankton tow in the Molokai Channel. They resemble pseuderichthus larvae very much, and it is possible to distinguish the two only

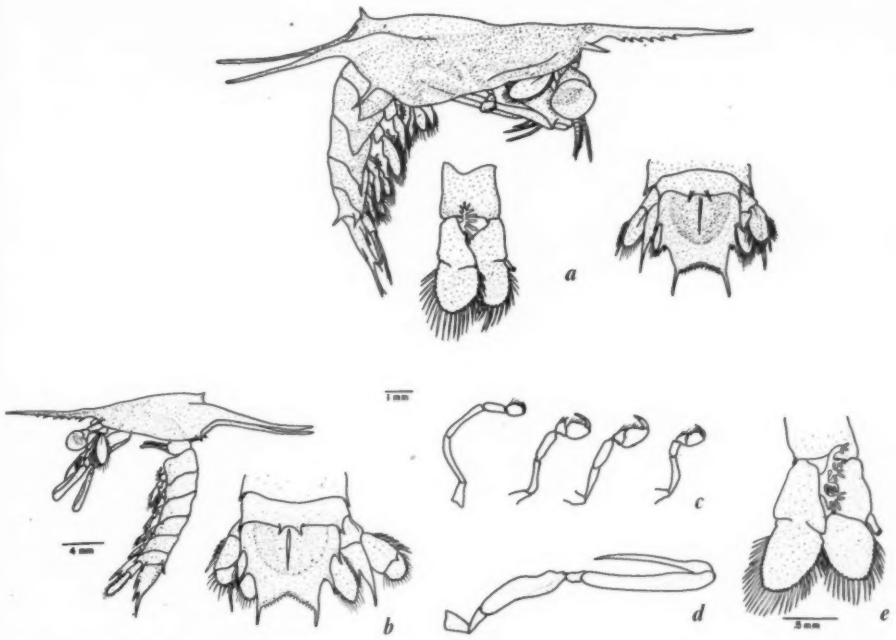

FIG. 28. Larval forms of *Odontodactylus*. *a*, Lateral aspect of odonterichthus larva, first abdominal appendage, and dorsal aspect of last abdominal somite, telson, and uropods; *b*, lateral aspect of odonterichthus larva and dorsal aspect of last abdominal somite, telson, and uropods; *c*, first, third, fourth, and fifth thoracic appendages of same; *d*, second thoracic appendage of same; *e*, first abdominal appendage of same.

by comparing the raptorial claws. In pseuderichthus larvae this appendage is finely pectinate along the upper margin of the propodus, and the dactylus is not inflated at the base. In odonterichthus, however, the raptorial propodus is not pectinate along its upper margin, and the dactylus is inflated at its base. In later stages the ischio-meral articulation of the raptorial appendage would be a useful diagnostic character, but none of the specimens has attained this condition, which is present in the adult. This genus is undoubtedly closely related to *Gonodactylus*, but it has been impossible to compare the larvae of the two genera because no specimens of the latter have been collected in Hawaiian waters. Claus (1872) and Brooks (1886) have both illustrated gonerichthus larvae which were collected from other regions, and comparisons with their figures show that the Molokai Channel specimens definitely belong to the odonterichthus type. Foxon (1932) uses the character of the long spines found on the telson of *Odontodactylus* larvae for separating them from *Gonodacytlus*, although he does not present any figures to illustrate his statements. Since no *Gonodactylus* larvae have been collected in the Hawaiian waters, I cannot say whether or not this is a valid character for the separation of the larvae of the two genera, but comparisons with Claus's and Brooks's figures of gonerichthus larvae show that the spines on the telson of their specimens are considerably shorter than those found in the present specimens. With this in mind I have placed the character in the key with the hope that some future worker who may find the gonerichthus larvae will be saved some effort in

trying to place them in their correct genus.

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The Role of Dehydration in the Development of Laterite[1]

G. Donald Sherman, Yoshinori Kanehiro, and Yoshito Matsusaka[2]

Soil formation in tropical regions is determined by the nature and extent of the chemical weathering of the soil-forming materials. The intense chemical weathering and the varying length of time of exposure of minerals to weathering have resulted in the development of a broad sequence of soil formation in the tropical areas of the world. Sherman (1949) has shown that the soils of the Hawaiian Islands exhibit a sequence of soil development which can be related to a sequence of mineral weathering as proposed by Jackson *et al.* (1948). This sequence of soil formation represents a series of successive stages of secondary mineral development with the following order of soils rich in: (1) primary minerals; (2) montmorillonite; (3) kaolinite; (4) hydrated sesquioxides; and (5) dehydrated sesquioxides. The end product of this weathering cycle would be either a ferruginous laterite or a bauxite laterite, depending on the environmental conditions. These two products represent two extremes of a wide range of weathered end-products, as the intermediate member —a ferruginous bauxitic laterite—is quite common (Harrison, 1934).

Ferruginous laterite was described by Buchanan (1807). As described by Buchanan, laterite is a soil horizon which has a very high content of iron oxides. These iron oxides exist as the minerals, limonite, goethite, hematite, and magnetite. The profile of the ferruginous laterite must have a horizon rich in iron oxide which will harden, on exposure, to an indurate layer with brick-like properties. The ferruginous horizon may contain concretions of iron oxide in which case it is a pisolithic laterite, or the iron oxide may exist as a lens in a porous matrix which is known as a vesicular laterite, according to Pendleton (1941). Ferruginous laterite may also develop as a massive horizon near or at the surface which on exposure will harden and develop a uniform, structureless crust, or corapace. Soils of this type have been described by Aubreville (1947, 1948), Chevalier (1948), and Sherman (1950).

The mode of origin, or formation, of ferruginous laterite has been a point of controversy. Glinka (1927) believed that laterites formed under both evergreen and savannah types of vegetation. Richthofen's views (1860) differed from Glinka's in that he postulated the formation of laterite under a former forest vegetation which had been succeeded by a shrub and grass vegetation. In other words, as soils degraded they could not support the evergreen forest; thus, the forest disappeared and was replaced by a lower level of vegetation. Harrassovitz (1930), Holmes (1914), and Campbell (1917) concluded from their studies that laterite formed only where climatic conditions were conducive to the upward movement of the dissolved soil sesquioxides, which would only occur under alternating wet and dry conditions. On the other hand, Pendleton (1941, 1942, 1946) believes that laterites are formed by the oxidation and

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precipitation of the iron oxides in the zone above the fluctuating water table. This layer is made up of concretions of iron oxide which will harden on exposure to give the ironstone laterite, a material suitable for building material. Finally, there are soil scientists who hold that laterite has developed by residual accumulation as the result of leaching and removal of silica. Marbut (1932) and Fox (1933) were the leading advocates of this hypothesis of the mode of formation of laterite.

In spite of the numerous hypotheses as to the origin of laterite, there are certain facts which are included in all proposals. One of these facts is that in the early stages the weathering surface is losing silica and bases. Desilication is taking place with the progressive development of soils having a sequence of minerals with a lower silica content. Secondly, as desilication proceeds the sesquioxides accumulate in the soil. These weathering processes are accelerated under high rainfall and high temperatures which are common to many tropical regions. Lastly, all ferruginous laterites harden on exposure. The hardened laterite is made up of lenses or concretions of iron oxides often cemented together by a kaolinitic clay.

A number of titaniferous ferruginous laterite crusts have been described in the Hawaiian Islands by Sherman (1952). Each profile of these soils has a massive indurate surface horizon having both a high bulk density and a high particle density. This hardened surface horizon is underlaid by a friable subsoil. This subsoil horizon possesses the bulk density of an average soil. Likewise, the particle density is lower than that of the surface horizon. Below the friable subsoil horizon is an impervious layer which may be the unweathered country rock, a plastic clay, or an unconformity-like relationship which may have developed by pedogenic processes rather than being a geological unconformity.

These laterite crusts were either barren or were covered by scattered bunches of grass or vines. However, some of the areas which exhibited the crust-like surface horizon had a fair amount of vegetation. These areas, also, exhibited a high bulk density and high particle density relationship such as is found in the barren crust areas. From many observations made during wet and dry weather, it was noted that the bulk density of the soil varied according to the soil moisture conditions. In a visit to a barren crust area on Kauai after a heavy rain, a marked difference was observed between the bulk density and hardness of the surface soil of the barren area and the adjacent identical soil under a vegetative cover. It has been observed that the crust will develop on irrigation ditch banks where wetting and drying have occurred at very frequent intervals. The appearance of the hardened crust can be associated with dry periods, suggesting that its formation is due to dehydration. Thus, it is possible that vegetation will protect the hydrated minerals from dehydration and prevent the crust formation.

A study has been conducted to determine the role of dehydration of the hydrated sesquioxides in the development of the laterite crust. The study also included the determination of the effect of dehydration on the physical and chemical properties of the soil. For this study two sets of soil samples from adjacent profiles were selected. The soil profiles were located on the slopes of the western rim of Waimea Canyon on the island of Kauai. A titaniferous ferruginous laterite crust covers a rather level bench on this slope. Profiles were selected at different areas of this laterite crust. The two main profiles used in this study were taken at the edge of the barren crust area so that the profile without a vegetative cover was taken only 3 feet from the site of the profile with a vegetative cover. The morphology of the two profiles was identical except for the obvious difference in the physical condition of the surface horizon. The characteristics of the two profiles are shown in Figure 1.

METHODS OF ANALYSIS

Soil samples were collected from the pro-

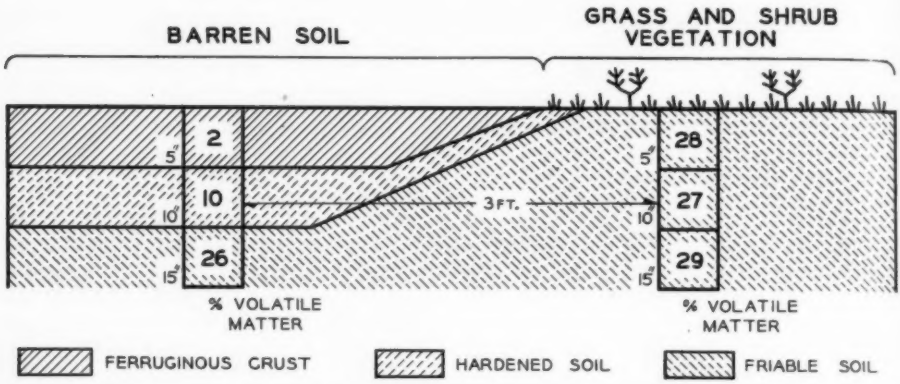

FIG. 1. The location and relationship of the hardened crust and vegetative cover of two adjacent profiles from Waimea Canyon, Kauai.

files as shown in Figure 1 and in a like manner from other similar areas, including the crust developed on an irrigation ditch bank. The bulk density, particle density, differential thermal analysis, cation exchange capacity, and content of the major oxides were determined for each soil sample. The bulk density of the soil was determined by two methods. The first was by removing the soil from a given space and determining its dry weight. The volume of soil was determined by fitting a plastic bag to the space occupied by the soil and ascertaining the amount of water required to fill the hole. The second method was similar except that the soil was taken by a sharp-edged cylinder of a known volume. The particle density of the soil was determined by the pycnometer (Wright, 1934). The cation exchange capacity and the oxide analysis were made by methods described by Piper (1944). Differential thermal analysis was made according to the procedure proposed by Norton (1939).

EXPERIMENTAL RESULTS

Bulk Density and Particle Density: The most striking characteristics of the laterite crust are the high apparent and true specific gravity. Fujimoto *et al.* (1948) have described a laterite crust in which the surface horizon contains more than 50 per cent heavy minerals. In the profile there is a tremendous difference between the indurate surface horizon and the friable layer in their bulk density and soil particle density. This same difference was present in the surface layer of the barren profile but was not apparent in the profile with a vegetative cover. In Table 1 the bulk densities and particle densities of the soils taken from a profile without vegetative cover and a profile with vegetative cover are given. The bulk density of the soil samples from the well-developed laterite crusts was 1.9 or greater, and their particle density was higher than 3.8. The bulk density of the soils from the profile with a vegetative cover was 1.0 or lower and the particle density ranged from 2.7 to 3.3. The highest bulk density and particle density, 2.5 and 4.1, respectively, were found in a fragment of the crust from an irrigation ditch bank wall. The data clearly demonstrate the obvious difference between the soils of the barren areas and those with a vegetative cover. The observations indicate that the vegetative cover does protect the soil from hardening to an indurate horizon. The differences are more clearly demonstrated in Table 2, which presents the averages of the different types of soil profiles in Table 1.

TABLE 1
A COMPARISON OF THE BULK DENSITY AND PARTICLE DENSITY OF DIFFERENT SOIL HORIZONS IN BARREN LATERITE CRUST AREAS WITH ADJACENT AREAS HAVING A VEGETATIVE COVER

BARREN SOILS (CRUST)				VEGETATIVE COVER (NO CRUST)			
LOCATION	DEPTH	BULK DENSITY	PARTICLE DENSITY	LOCATION	DEPTH	BULK DENSITY	PARTICLE DENSITY
	Inches				*Inches*		
Laterite crust Waimea Canyon Site A	0– 7	2.0	3.84	Waimea Canyon Site C near sites A and B	0– 5	0.8	2.86
Laterite crust Waimea Canyon Site A—friable layer	7–14	1.1	2.71	Waimea Canyon Site C near sites A and B	5–10	0.9	2.99
Laterite crust Waimea Canyon Site B	0– 7	2.2	4.43	Waimea Canyon Site C near sites A and B	10–15	0.9	2.82
Laterite crust Waimea Canyon Site B—friable layer	7–14	0.8	2.21	Waimea Canyon Site C near sites A and B	15–20	1.0	2.91
Laterite crust Lower Waimea Canyon Irrigation ditch bank Site E	0– 5	1.9	3.98				
Laterite crust Lower Waimea Canyon Irrigation ditch bank Site E	5–10	2.1	4.16	Waimea Canyon Site D above site C	Matted roots on surface	0.9	2.75
Laterite crust Lower Waimea Canyon Irrigation ditch bank Site E	10–15	2.1	4.25	Waimea Canyon Site D above site C	0– 5	0.9	3.24
Hardened soil Lower Waimea Canyon Irrigation ditch bank	0– 5	1.4	4.00	Waimea Canyon Site D above site C	5–10	0.9	3.21
Hardened soil Lower Waimea Canyon Irrigation ditch bank	5–10	1.3	3.81	Waimea Canyon Site D above site C	10–15	1.0	3.34
Hardened soil Lower Waimea Canyon Irrigation ditch bank	10–15	1.3	3.79				
Loose clod Irrigation ditch bottom	....	2.5	4.14				

Chemical Composition: The soil samples from the two profiles shown in Figure 1 were analyzed for major oxide constituents, and the data obtained are given in Table 3. A marked difference was found in the amounts of certain constituents and also in the weight loss on ignition. The soil of the surface horizon from the area having a vegetative cover showed a loss of weight amounting to 28 per cent on ignition, whereas the soil from the same horizon of the barren profile lost a little over 2 per cent. The same data from the 10–15-inch

TABLE 2

THE AVERAGE BULK DENSITY AND PARTICLE DENSITY OF A SERIES OF FERRUGINOUS LATERITES AT DIFFERENT DEGREES OF HARDENING

AVERAGE	SAMPLES FROM CRUST	SAMPLES FROM HARDENED SOIL	SAMPLES FROM PROFILES HAVING VEGETATION	SAMPLES FROM FRIABLE SUBSOIL
Bulk density	2.13	1.33	0.91	0.95
Particle density	4.13	3.87	3.01	2.46

layer of both profiles showed practically no difference in their loss of weight on ignition, being 26 and 28 per cent.

The content of iron and titanium oxides is the highest in the soil from the 0–5-inch and 5–10-inch layers of the profile of the barren area, while the 10–15-inch layer of both profiles has a very similar amount of these oxides. The aluminum oxide content of soil from the 0–5-inch and 5–10-inch layers of the profile with the vegetative cover is higher than that for the corresponding soil layers of the profile from the barren area. The soils from the profile with a vegetative cover are less acid than the soils from the barren area. In the former the soil reaction ranges from *p*H 4.4 to 4.6 and in the latter from *p*H 3.8 to 4.2.

In Table 4 the data obtained from the analysis of cation exchange capacities of the soil are given. The cation exchange capacity of the soils shows the same relationship as the loss on ignition. The soil from the surface horizon of the profile from the area having a vegetative cover has a much higher exchange capacity than that from the surface horizon of the profile from the barren area, being 41.0 and 3.7 milliequivalents per 100 grams, respectively. Likewise, a difference existed in the 5–10-inch layer of the two profiles in which the cation exchange capacities were 37.0 and 15.6 milliequivalents per 100 grams, respectively. The cation exchange capacities of the 10–15-inch layer were very similar, being 38.4 and 34.9 milliequivalents per 100 grams. The organic matter content of the soil with a vegetative cover was higher than that found in the barren area. The organic matter content is not of sufficient quantity to explain this change in cation exchange capacity, so de-

TABLE 3

THE CHEMICAL COMPOSITION OF LATERITE PROFILES; A COMPARISON OF EFFECT OF DEHYDRATION DUE TO EXPOSURE ON CHEMICAL COMPOSITION

DEPTH	*p*H	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	LOSS ON IGNITION
Soil with vegetative cover (no crust)						
Inches		*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
0– 5	4.6	7.50	13.00	41.80	6.03	27.92
5–10	4.6	7.84	15.45	40.99	6.29	26.78
10–15	4.4	14.78	22.60	27.40	4.34	28.53
Barren soil (crust)						
0– 5	3.8	6.46	4.13	56.02	31.02	2.06
5–10	4.0	5.68	9.46	60.63	11.87	10.23
10–15	4.2	13.01	22.58	32.10	5.67	25.72

TABLE 4

THE RELATIONSHIP BETWEEN LOSS ON IGNITION AND CATION EXCHANGE CAPACITY UNDER BARREN LATERITE CRUST AND ADJACENT SOIL WITH A VEGETATIVE COVER

DEPTH	BARREN SOIL (CRUST)				SOIL WITH VEGETATION (NO CRUST)			
	*p*H	ORGANIC MATTER	LOSS ON IGNITION	CATION EXCHANGE CAPACITY	*p*H	ORGANIC MATTER	LOSS ON IGNITION	CATION EXCHANGE CAPACITY
Inches		*Per cent*	*Per cent*	*m.e./100g.*		*Per cent*	*Per cent*	*m.e./100g.*
0– 5	3.8	1.1	2.0	3.7	4.6	8.2	27.9	41.0
5–10	4.0	...	10.2	15.6	4.6	...	26.8	37.0
10–15	4.2	...	25.7	34.9	4.4	...	28.5	38.4

hydration is considered to be the cause of its reduction.

Differential Thermal Analysis: The thermal curves obtained from the differential thermal analysis are given in Figure 2 for the soil profile from the barren area and Figure 3 for the soil with a vegetative cover. There is a marked difference in these two sets of curves. The curve for the surface horizon of the soil with a vegetative cover showed a strong exothermic peak at 180°C., whereas the surface soil from the barren area showed no thermal reaction at this temperature. In fact, the curve of the latter soil is very similar to that obtained from a sample of hematite. The thermal curves of the subsoil horizons of both profiles exhibit thermal peaks at 180°C. to 190°C., but none of the soils exhibited a peak at 710°C. which is characteristic of montmorillonite. The thermal curves of this type are probably due to the existence of amorphous hydrated oxides of iron, aluminum, and titanium. Some of the soils have a small peak at 350°C. which is probably due to goethite.

As the differential thermal analysis was made on the untreated soils, the question arises as to whether these curves are influenced by the difference in organic matter content of the soil. The surface soil of the profile with a vegetative cover has a higher content of organic matter than that of surface soil of the barren area. It will be noted that the thermal curves of the 10–15-inch layer of the profile with a vegetative cover are exactly the same as that of the surface horizon. As this horizon has a low organic matter content, the minerals of the soil must be responsible for its thermal characteristics. The loss of water below 300°C. also substantiates the fact that dehydration of minerals is responsible for thermal characteristics of the soil, as the loss of water is the greatest in those soils showing thermal peaks at 180°C.

The ferrous iron content was determined in the surface soils from the two profiles. The soil from the profile with a vegetative cover contained from two to five times as much ferrous iron as the soil from the barren area. As the surface soil from the barren areas is magnetic and has a low ferrous iron content, the presence of maghemite is suggested in these soils. Furthermore, this would suggest the existence of the lepidocrocite-maghemite system in these soils as maghemite is the product of dehydration of lepidocrocite. Further evidence is needed to establish the validity of this suggestion.

DISCUSSION

The results of this study have established that the indurate laterite crust horizon is developed by the dehydration of the hydrated iron and titanium minerals in the soil. The thermal curves from the differential thermal analysis and the loss of water under 300°C. of the two profiles have shown that hardening

of the barren area is due to dehydration. In the dehydration of the colloidal hydrated iron oxides, water is lost and the oxides are converted to hematite or related dehydrated iron oxides. The process will cause an increase in particle density and, according to Fujimoto *et al.* (1948), an increase in particle size. The question arises as to the length of time required for a ferruginous horizon to harden to the laterite crust on exposure. Aubert (1949, 1950) has reported the formation of laterite crusts under normal conditions in 35 to 60 years. Chevalier (1949) states that, if the forest is removed by cutting, burning, or loss of cover due to other reasons, the senile stage (the laterite crust) will develop very rapidly. Davis (1940) found that because of the clear culture required in the culture of teak and because teak trees lose their leaves during the dry season, the laterite crust will develop in a very short period of time [one dry season]. The hardening of Hawaiian soils on exposure is very rapid, occuring in less than a year.

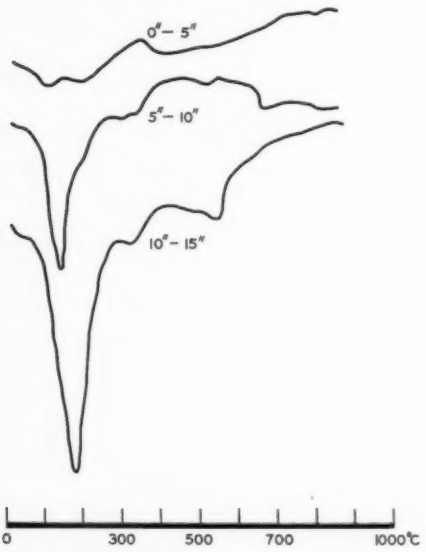

FIG. 2. The differential thermal curves of the profile from the barren area of a humic ferruginous latosol soil.

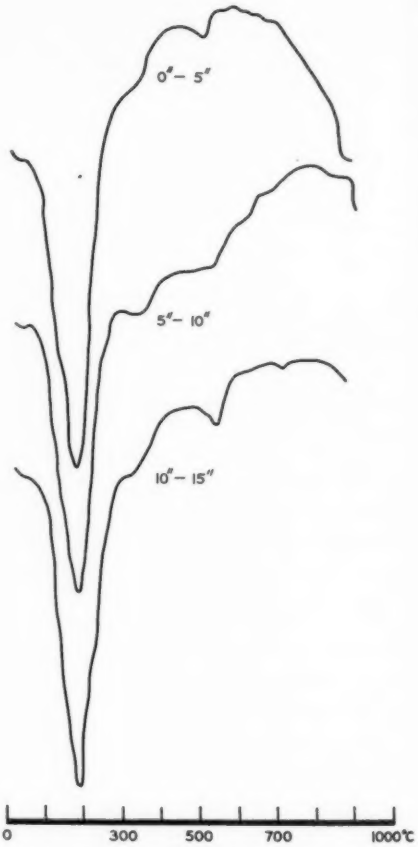

FIG. 3. The differential thermal curves of a profile with a vegetative cover of a humic ferruginous latosol soil.

The dehydration of the soil causes very important changes in the physical and chemical properties of the soil. There is an obvious change in compaction, bulk density, particle density, and particle size. The most important change is the loss of cation exchange capacity. It has been observed that these barren areas are infertile. This infertility very likely is due to the loss of adsorptive surface and to the poor physical condition of the soil. The reforestation of these laterite areas is a slow process as the conditions for growth are very poor.

It has been established by Fieldes *et al.* (1952) that the amorphous colloidal hydrated oxides have a high cation exchange capacity. In a personal communication from these workers, they report that they have found that the hydrated iron oxides lose cation exchange capacity on dehydration. These observations support the findings in this study.

SUMMARY

A study has been conducted to ascertain the role of dehydration in the development of the indurate laterite crust. The following conclusions appeared to be justified:

1. The data obtained from differential thermal analysis, elemental analysis, and physical measurements have established that the dehydration of the colloidal hydrated oxides of the soil is responsible for the development of the indurate laterite horizon when exposed to a drying environment.
2. The dehydration of the titaniferous ferruginous horizon will increase the bulk density and particle density of the soil.
3. Dehydration causes the development of inert dehydrated minerals as shown by the data on loss on ignition and cation exchange capacity. The colloidal hydrated iron oxide is converted to hematite or similar iron oxide minerals.
4. The rates of dehydration of ferruginous layers will probably vary according to the mineral content of soil and the vegetative and climatic environments.

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A Discussion of the Trematode Genus *Schistorchis* (Family Lepocreadiidae) with Descriptions of Two New Species from Hawaii[1]

MARY LOUISE HANSON[2]

THIS REPORT is the first to be based on specimens collected during June and July of 1949 at the Marine Laboratory of the University of Hawaii, Honolulu. To Dr. Robert W. Hiatt, chairman, and to the members of the Department of Zoology and Entomology at the University of Hawaii I wish to extend my sincere appreciation for the laboratory space and the laboratory equipment which were furnished me. To Dr. William A. Gosline, ichthyologist in the Department of Zoology and Entomology at the University of Hawaii, the author is indebted for his invaluable assistance in identifying the fish hosts. The fishes were made available through the generosity and assistance of Mr. Spencer W. Tinker, Director of the Honolulu Aquarium. From all these individuals, and from Dr. H. W. Manter under whose direction the work was done, the author has received valued encouragement. The trip to Hawaii was made possible by a Robert A. Wolcott Scholarship granted by the University of Nebraska Foundation.

The trematodes, upon removal from the hosts, were killed under a cover glass with F.A.A. fixative (formalin, alcohol, and acetic acid). Storage for a short time was in 70 per cent alcohol. The worms were stained in Delafield's haematoxylin, cleared in xylol, and mounted in Permount.

Type specimens are being deposited at the United States National Museum.

The genus *Schistorchis* Lühe, 1906, now recognized to be quite distinct from *Pleorchis* Railliet, 1896, with which it was once associated, has the following characteristics: medium to large, elongated Homalometroninae; smooth or spined anteriorly; oral sucker terminal or subterminal; ceca long, with or without ani; excretory vesicle I-shaped with long collecting tubules often reaching pharyngeal level; genital pore median or very slightly to the left, just anterior to the acetabulum; cirrus sac absent; genital sinus present; eleven testes intercecal, tandem in a single row or arranged more or less in a double row; ovary pretesticular, median or to the right; seminal receptacle and Laurer's canal present; uterus not extending posterior to the ovary; parasites of marine fishes. Type species: *S. carneus* Lühe, 1906.

In addition to the type species the genus contains four species: *S. callyodontis* Yamaguti, 1942; *S. sigani* Yamaguti, 1942; *S. stenosoma;* and *S. zancli*. The latter two species are here described. The following key to the genus *Schistorchis* is proposed:

1. Testes not in a single median row.....3
   Testes in a single median row.....2
2. Uterus preovarian.....*S. zancli*
   Uterus reaching at least to mid-ovary.....*S. stenosoma*
3. Testes not in two lateral, opposite groups.....4
   Testes in two lateral, opposite groups.....*S. carneus*

[1] Studies from the Department of Zoology, University of Nebraska, No. 261.

[2] University of Nebraska State Museum, Lincoln. Manuscript received July 22, 1952.

4. Acetabulum near cecal bifurcation.....
.....*S. callyodontis*
Space between acetabulum and cecal bifurcation nearly twice length of acetabulum
.....*S. sigani*

SYSTEMATIC POSITION

Lühe (1906: 102) and subsequent authors have associated the genus *Schistorchis* Lühe, 1906, with the genus *Pleorchis* Railliet, 1896. Johnston (1913: 383–386) named *Pleorchis oligorchis* which Odhner (1928: 5) considered identical with the previously described *Schistorchis carneus*. Stunkard (1931: 713–714) quoted the latter paper, apparently in agreement. Yamaguti (1942: 362) referred to "*Schistorchis oligorchis* (Johnston, 1914) [correctly 1913] which is very closely related to if not identical with, *Schistorchis carneus*," seeming to have reached the conclusion independently. Manter and Van Cleave (1951: 331) likewise referred to "*Pleorchis oligorchis* Johnston, 1914 [sic] . . . transferred to *Schistorchis* by Yamaguti (1942)."

Poche (1926: 1–458) placed the genus *Schistorchis* with *Pleorchis* in the family Pleorchiidae where it remained until 1942. Cable and Hunninen (1942: 306) observed that "the genera *Pleorchis* and *Schistorchis* for which Poche (1925) [correctly 1926] erected the family Pleorchiidae, do not seem to be at all closely related" and considered *Pleorchis* among the Acanthocolpidae. Nothing was suggested for *Schistorchis*.

At very nearly the same time, Yamaguti (1942: 364) proposed the separation of *Pleorchis* and *Schistorchis* and erected the new family Schistorchiidae to include *Schistorchis*, and also *Apocreadium* Manter, 1937, and *Choanodera* Manter, 1940, which he considered to resemble *Schistorchis* closely. Both *Choanodera* and *Apocreadium* were considered by Manter (1940: 344–348) as members of the family Gyliauchenidae. Cable and Hunninen (1942: 309) considered the gyliauchenids as related to Lepocreadiidae, and Manter (1947: 264) stated that "*Apocreadium* and *Choanodera* are so similar to *Homalometron* (differing chiefly in their lymphatic vessels) that they should be transferred to the Homalometroninae, family Lepocreadiidae." Thus *Schistorchis* is the only remaining genus in the family Schistorchiidae.

The genus *Schistorchis* agrees very well with the description of Homalometroninae in the family Lepocreadiidae Nicoll, 1934, as proposed by Cable and Hunninen (1942: 308). Although this is the first report of multiple testes among the Homalometroninae, they are present among the Lepocreadiinae and are provided for in the description of the family.

The presence or absence of ani is often difficult to determine in a whole mount. Both *Schistorchis callyodontis* and *S. sigani* were described from a single specimen. Both Lühe and Johnston described *S. carneus* without ani, but Odhner (1928: 5) found them to be present when he sectioned specimens. Stunkard (1931: 723–724) observed that secondary connections between the intestinal ceca and the exterior have developed independently in several different families and that such communications are not uniformly present in all members of those families in which they do occur. The conclusion was drawn that such connections are relatively recent acquisitions which developed after the families became differentiated.

It is proposed that the genus *Schistorchis* be classified as Homalometroninae, family Lepocreadiidae, and that the family Schistorchiidae become a synonym of Lepocreadiidae.

Schistorchis stenosoma n. sp.

Fig. 1*a–d*

HOST: *Cantherines pardalis* (Ruppell), file fish; in all of 7 specimens examined.

LOCATION: Intestine.

DESCRIPTION (based on a series of 31 specimens): Body 7 or 8 times longer than wide, 1.701 to 4.271 mm. long, 0.211 to 0.635 mm. wide; width about equal along most of body length, but slightly wider immediately ante-

rior to acetabulum; both ends slightly tapered. Rows of widely spaced, short, blunt spines rarely extend as far posterior as acetabulum. Ventrally spines somewhat heavier and extend more posteriorly. Traces of eye-spot pigment present. Oral sucker subterminal, 0.161 to 0.300 mm. long, 0.175 to 0.315 mm. wide, very nearly round. Acetabulum 1/4 to 1/5 body length from anterior end; 0.117 to 0.234 mm. long by 0.119 to 0.234 mm. wide, very nearly round; sucker ratio 1:0.530 to 1:0.801. Prepharynx very short, appearing absent in many specimens; pharynx rounded, 0.080 to 0.146 mm. long by 0.098 to 0.169 mm. wide; esophagus 0.029 to 0.131 mm. long; bifurcation immediately anterior to acetabulum; area of bifurcation voluminous; ceca parallel to body walls, each terminating in anus; ani terminal, each encircled with cuticular furl. Genital pore median or slightly to left of median line, at anterior border of acetabulum. Testes 11, intercecal, serial and contiguous; 0.044 to 0.190 mm. long by 0.060 to 0.208 mm. wide, anterior testes usually larger than posterior. Pattern of vasa efferentia varied. Usually a single vas efferens from each testis leading to a vas deferens; in some instances two vasa efferentia arise from a common origin on a testis (Fig. 1*b*). Two vasa deferentia just median to ceca enter posterior portion of seminal vesicle separately. Seminal vesicle bipartite; posterior portion 0.095 to 0.354 mm. long by 0.085 to 0.248 mm. wide, rounded, extending posteriorly from level of mid-acetabulum, never reaching ovary, joined to anterior portion by a short, narrow tube; anterior portion much smaller than posterior, longer than wide, variable in size, opening into genital sinus with uterus. Prostatic cells loosely surround anterior portion of seminal vesicle. Ovary round, 0.073 to 0.162 mm. long by 0.080 to 0.162 mm. wide, lying to right of median line just anterior to anterior testis, but never touching it. Uterus with 3 or 4 intercecal coils; entering genital sinus dorsal to acetabulum (Fig. 1*c*). Uterus always extends posteriorly at least to anterior margin of ovary, usually to posterior margin of ovary, occasionally slightly beyond ovary although never reaching anterior testis. Mehlis' gland dorsal to ovary, diffuse, extending from anterior edge of anterior testis to level of mid-ovary, intercecal. Laurer's canal well developed, opening midway between acetabulum and ovary, dorsal to left cecum; a short, narrow tube directed first medianly and then posteriorly, enlarging into receptacle-like por-

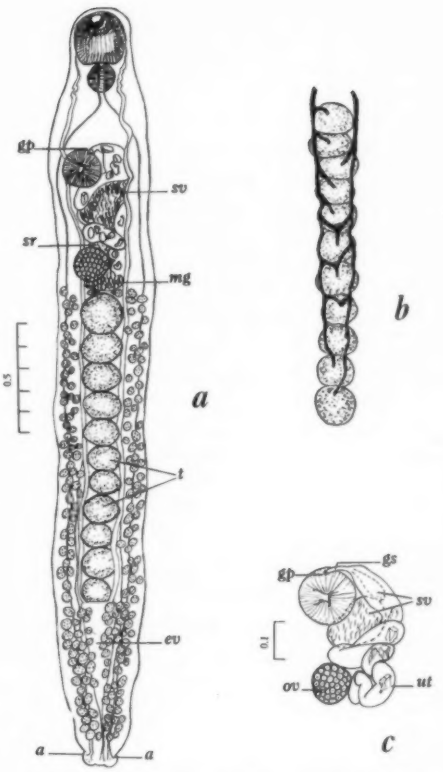

FIG. 1. *Schistorchis stenosoma* from *Cantherines pardalis* (Ruppell), file fish. *a*, Ventral view; *b*, pattern of vasa efferentia and vasa deferentia (diagrammatic); *c*, terminal genital ducts (ventral view); *d*, oötype region (dorsal view). *a*, *c*, and *d* drawn with the aid of a camera lucida. Projected scale in millimeters. Abbreviations: *a* = anus, *e* = egg, *ev* = excretory vesicle, *gp* = genital pore, *gs* = genital sinus, *lc* = Laurer's Canal, *mg* = Mehlis' gland, *ov* = ovary, *sr* = seminal receptacle, *sv* = seminal vesicle, *t* = testis, *ut* = uterus.

tion, then again narrowly tubular to ootype. Connection between ootype and true seminal receptacle clearly discernible (Fig. 1*d*). Seminal receptacle 0.065 to 0.190 mm. long by 0.078 to 0.218 mm. wide, as large as or larger than ovary; slightly anterior to, more median and more dorsal than ovary; vitellaria follicular from level of anterior testis (3 or 4 follicles anterior to anterior testis) to posterior end of body; lateral and ventral to ceca, very few intercecal follicles anterior to posterior testis, then becoming confluent. Eggs relatively few (7 to 15), usually collapsed, 37 to 68 by 22 to 43 μ, usual range 51 to 56 by 31 to 36 μ. Excretory pore terminal between anal furls; excretory vesicle I-shaped, extending to posterior edge of posterior testis, joined there by principal pair of collecting tubules. Tubules extend anteriorly just median to ceca, cross ceca ventrally at acetabular level, narrow and tend to coil slightly at pharyngeal level, then continue forward lateral to oral sucker.

COMPARISONS: *S. stenosoma*, with the 11 testes in a single, median row, with the uterus found at least as far posterior as mid-ovary and sometimes slightly posterior to the posterior border of the ovary, and with body spines, differs from all previously described species of *Schistorchis*.

S. carneus was originally described with cirrus sac and without ani, but Yamaguti (1942: 362) concluded that the cirrus sac was absent, and Odhner (1928: 5) described the ani. *S. carneus* differs from *S. stenosoma* in its bulkier body proportions, the retracted oral sucker, the smaller pharynx, the apparent absence of an esophagus, the long excretory vesicle which extends anterior to the ovary, and the arrangement of the testes in two lateral groups.

S. callyodontis differs from *S. stenosoma* by its lack of ani, the longer excretory vesicle, the ovary which is at the same level as the anterior testis, the nearly equal size of the suckers, the testes arranged irregularly in two rows, and the heavy musculature of the anterior portion of the body.

S. sigani differs from *S. stenosoma* by its lack of ani, the longer excretory vesicle, the very short esophagus, the wide area between the intestinal bifurcation and the acetabulum, the nearly equal size of the suckers, the small pharynx, the testes which are arranged irregularly in two rows, and the larger eggs.

The name *stenosoma* is a combination of steno- (narrow) and soma (body), referring to the relative slenderness of the body.

Schistorchis zancli n. sp.

Fig. 2*a*, *b*

HOST: *Zanclus cornutus* (L.), Moorish idol or kihikihi loulu; in 1 of 9 specimens examined.

LOCATION: Intestine.

DESCRIPTION (based on two specimens): Body elongate, 2.409 to 2.643 mm. long, 0.606 to 0.686 mm. wide; widest at acetabular level, tapering abruptly anteriorly at esophageal level and posteriorly at level of second testis; width of narrower posterior portion nearly equal; anterior end blunt, posterior end rounded. A few small, scattered spines present anterior to level of esophagus. Traces of eyespot pigment present. Oral sucker subquadrate, terminal, 0.168 to 0.196 mm. long by 0.256 mm. wide. Acetabulum 1/3 body length from anterior end; rounded, 0.197 to 0.204 mm. long by 0.183 to 0.190 mm. wide; sucker ratio 1:0.715 to 1:0.742. Very short prepharynx observed in one specimen; pharynx 0.119 to 0.133 mm. long by 0.128 to 0.146 mm. wide, nearly rectangular; esophagus 0.043 to 0.085 mm. long; ceca wide anteriorly, narrowing posterior to acetabulum, nearly parallel to body walls, each with ventral, subterminal anus. Genital pore slightly to left of median line at anterior border of acetabulum. Testes 11, largely intercecal but occasionally ventral to median portion of ceca, serial and contiguous, 0.080 to 0.168 mm. long by 0.141 to 0.199 mm. wide, ellipsoidal to ovoid in shape. Seminal vesicle 0.256 to 0.285 mm. long by 0.183 to 0.219 mm. wide, saccular, with slightly swollen tube extending

from seminal vesicle to shallow genital sinus. Seminal vesicle ovoid, extending posteriorly nearly to ovary, narrowing into nonmuscular pars prostatica surrounded by several prostatic cells. Cirrus lacking. Ovary rounded, 0.124 to 0.153 mm. long by 0.146 to 0.153 mm. wide, lying to right of median line, contiguous with anterior testis. Short uterus without lateral coils, with 2 straight, longitudinal limbs, one ventral, one dorsal; latter joining pars prostatica near genital pore (Fig. 2*b*), intercecal, to left of median line, preovarian and well filled with eggs. Mehlis' gland dorsal and to left of ovary, diffuse, extending from level of mid-ovary anteriorly, slightly larger than ovary. Laurer's canal well developed, opening dorsal to left cecum at level of seminal vesicle, directed at first anteriorly than at mid-acetabular level turning backward; basal portion near ovary swollen. Seminal receptacle large, claviform, lying dorsal to and slightly anterior to ovary. Vitellaria of small follicles often grouped 2 or 3 together, extending from level of posterior edge of acetabulum to very near posterior end of body, lateral and ventral to ceca, somewhat confluent posterior to testes. Prominent yolk ducts extend from both sides at level of ovary, ducts seemingly swollen into reservoirs in one specimen. Eggs usually collapsed, 48 to 54 by 36 to 43 μ (majority 51 to 53 by 36 to 39 μ). Excretory pore ventral, subterminal, slightly anterior to ani and on median line; I-shaped vesicle, extending to posterior edge of posterior testis, joined there by principal pair of collecting tubules; tubules extend anteriorly just median to ceca, cross ceca ventrally beginning at level of ovary, continuing forward to pharyngeal level.

COMPARISONS: *S. zancli* is most similar to *S. stenosoma* of the other known species of the genus. *S. zancli* is like *S. stenosoma* and different from all other species in the genus in the possession of body spines, and in the presence of 11 testes arranged in a single, median row. It differs from *S. stenosoma* in that it has a more rhomboidal oral sucker, a larger, more rectangular pharynx, a greater angle at the origin of the ceca, a relatively more posterior acetabulum, more anterior extent of the vitellaria, fewer and smaller vitelline follicles, a more robust body, a preovarian uterus, ellipsoidal or ovoid rather than round testes, a relatively shorter posttesticular space, a nonmuscular pars prostatica, a non-bipartite seminal vesicle, subterminal ani without cuticular furls, and a subterminal excretory pore.

The name *zancli* refers to *Zanclus*, the genus of the host.

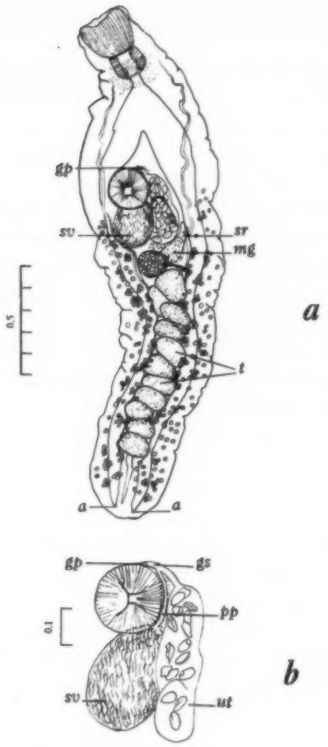

FIG. 2. *Schistorchis zancli* from *Zanclus cornutus* (L.), Moorish idol or kihikihi loulu. *a*, Ventral view; *b*, terminal genital ducts (ventral view). Drawn with the aid of a camera lucida. Projected scale in millimeters. Abbreviations: *a* = anus, *gp* = genital pore, *gs* = genital sinus, *mg* = Mehlis' gland, *pp* = pars prostatica, *sr* = seminal receptacle, *sv* = seminal vesicle, *t* = testis, *ut* = uterus.

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The *Aedes* Mosquitoes of the Philippine Islands
III. Subgenera *Aedimorphus, Banksinella, Aedes,* and *Cancraëdes* (Diptera, Culicidae)[1]

KENNETH L. KNIGHT AND WILLIAM B. HULL[2]

INTRODUCTION

THIS IS THE LAST of a series of three papers dealing with the *Aedes* fauna of the Philippine Islands. Part I (Knight and Hull, 1951) contained the general introduction, the keys to the adults and larvae, and the species treatments for the subgenera *Mucidus*, *Ochlerotatus*, and *Finlaya*. Part II (Knight and Hull, 1952) dealt with the subgenera *Skusea*, *Christophersiomyia*, *Geoskusea*, *Rhinoskusea*, and *Stegomyia*. In this part the remaining aedine subgenera known from the Philippines are considered, i.e., *Aedimorphus*, *Banksinella*, *Aedes*, and *Cancraëdes*.

All the necessary introductory information is given in Part I, and only explanations needed for an understanding of the abbreviations and symbols used are repeated here.

A dagger(†) denotes types that have been examined by us.

The following abbreviations are used in the descriptions. Adult: *apn*, anterior pronotal lobe; *ppn*, posterior pronotal lobe. Larva: *isc*, inner or upper caudal hair of the anal segment; *osc*, outer or lower caudal hair of anal segment; *lh*, lateral hair on anal plate.

Figures are not drawn to scale.

The following abbreviations are used in the species distribution sections to indicate the present locations of specimens examined. A.N.S.P., Academy of Natural Sciences of Philadelphia; C.A.S., California Academy of Sciences; U.S.N.M., U. S. National Museum; B.M., British Museum (Natural History); C.C., Cornell University; R.K.L., specimens from the collection of Naval Medical Research Unit No. 2 on which nothing has been previously published and which are now deposited in the U. S. National Museum, the Johns Hopkins University, the California Academy of Sciences, the British Museum, and the Knight collection.

SYSTEMATICS

Subgenus AEDIMORPHUS Theobald

1903. *Aedimorphus* Theobald, Mon. Cul. 3: 290. Genotype: *domesticus* Theobald (Africa).

1905. *Reedomyia* Ludlow, Canad. Ent. 37: 94. Genotype: *pampangensis* Ludlow (Philippines).

ADULT: Brown species, some with distinctive areas of silvery scaling. In general related to *Stegomyia*, but all the Philippine species distinct from that subgenus in the form of the male palpi (except the undescribed species mentioned in the discussion of *wainwrighti*) and of the dististyle of the male terminalia. Male palpi longer than the proboscis; segments IV–V down-tilted, numerous long hairs arising laterally and apically on the distal portion of III and all along IV–V (the unde-

[1] The opinions or conclusions contained herein are those of the authors and are not to be construed as official or reflecting the views of the Navy Department or of the Naval service at large. Manuscript received August 12, 1952.

[2] Naval Medical Research Institute, Bethesda, Maryland. Lieutenant Commander, MSC, USN, now with Malaria and Mosquito Control Unit #1, Naval Air Station, Jacksonville, Florida, and Lieutenant, MSC, USN, respectively.

scribed species mentioned above has slender, relatively hairless palpi as in *Stegomyia*). Vertex dorsum with a variable area of narrow scales medially (confined to nape in *wainwrighti* and in some specimens of *ostentatio;* all narrow-scaled in v. *nocturnus*), remainder broad-scaled. Scutellum either broad- or narrow-scaled. Paratergite with or without scales. No lower mesepimeral bristles. Fore and mid-tarsal claws of male unequal, each unidentate; hind claws equal, simple. Tarsal claws of female equal, fore and mid each unidentate; hind simple. *Terminalia:* Basistyle without true apical lobes and without basal lobe, except in v. *nocturnus* where a setose basal plaque occurs. Dististyle greatly swollen apically, except in v. *nocturnus*, the enlarged portion bearing a complicated arrangement of hairs and modified setae. Claspettes absent. Mesosome divided into two lateral plates, each of which bears several teeth laterally.

LARVA: Separable from all the other subgenera in the Philippines, except *Ochlerotatus* and some specimens of the *Finlaya* species *leucopleurus* and *aureostriatus*, by the possession of an acus on the anal plate. Antennal hair tuft with 5–13 branches. Head hair 4 with 2–8 branches, 5 and 6 with 1–7. Comb with 16–26 small scales in a patch, or with 8–10 large teeth in an irregular, partially double row. Siphon with an attached acus; 12–21 pecten teeth, each with one or more large ventral denticles; distal teeth more widely spaced and without denticles. Anal plate incomplete; ventral brush of 12–16 tufts, all but basal 1–4 borne on a prominent, laterally connected barred area. Habitat chiefly rain-filled temporary pools, but also occasionally such places as stream margins and permanent pools and ditches.

DISTRIBUTION: Seven species are known from the Philippines. This subgenus is largely confined to the Ethiopian and Oriental regions.

SYSTEMATICS: Edwards (1932: 166) divided the subgenus into eight groups. Knight and Hurlbut (1949: 29) modified this classification by combining Group D with Group C.

No sharp division occurs between *Stegomyia* and *Aedimorphus*, the two subgenera being apparently intimately connected through Group A (*apicoannulatus*-group) of the Ethiopian region and through Group B (*nummatus*-group) of the Oriental region (via Group E of *Stegomyia*).

In the Philippine fauna, Group C is represented by *alboscutellatus*, *mindoroensis*, *pampangensis*, and *punctifemore*. In that fauna it is separable from Group G, represented only by *vexans nocturnus*, in the absence of a basal lobe on the basistyle and in the possession of an apically swollen and markedly modified dististyle. The positions of *ostentatio* and *wainwrighti* are uncertain because the males are as yet undescribed. The other groups are not represented in the Philippines.

Aedes (Aedimorphus) pampangensis (Ludlow)

Figs. 1, 2

1905. *Reedomyia pampangensis* Ludlow, Canad. Ent. 37: 94 (3 females). Type locality: Philippines. Angeles, Pampanga Prov., Luzon (Whitmore). However, the specimen in the U.S.N.M. is labeled "Camp Wm. McKinley, Rizal, P. I., Nov. 3. 05." in Ludlow's handwriting. Type: Female (holotype) in U.S.N.M.†

1922. *Aedes* (*Ecculex*) *alboscutellatus*, Theobald. Edwards, Indian Jour. Med. Res. 10: 467. In part.

1925. *Aëdes* (*Aëdimorphus*) *niveoscutella* Theobald. Dyar and Shannon, Insecutor Inscitiae Menstruus 13: 76.

1932. *A.* (*A.*) *alboscutellatus* Theobald. Edwards, Genera Insectorum. Fasc. 194, p. 167, Barraud, 1934, 250. In part.

1945. *Aedes* (*Aedimorphus*) *pampangensis* (Ludlow). Bohart, U. S. NavMed. 580, p. 53. Different combination.

ADULT: Vertex dorsum with a median narrow-scaled area. Scutum uniformly brown-

scaled. Scutellum with broad silvery scales. Tarsi all dark.

Male. Head: Proboscis pale, apical one-fourth dusky, particularly dorsally. Palpi slightly longer than proboscis; dark; segments IV–V down-tilted, numerous long hairs arising apically and all along IV–V. Vertex with a narrow area of narrow pale scales along either side of mid-line, a line of narrow pale scales along the dorsal portion of the eye margins; remainder of vertex with broad yellowish-white scales; brown upright-forked scales over the whole dorsum. *Thorax:* Scutal integument brown; clothed with small, narrow brown scales, may be a few narrow yellowish scales along the anterior margin, over the wing base, and on the prescutellar area. Scutellar lobes covered with broad silvery-white scales. *Apn* with a few narrow yellowish scales; *ppn* sparsely covered with narrow brownish and yellowish scales. Propleuron, subspiracular area, and paratergite each with some narrowed yellowish scales; upper sternopleuron, lower posterior sternopleuron, and upper mesepimeron each with small patch of broad creamy-white scales. *Legs:* Fore femur with anterior surface dark, paler basally; posterior surface with dorsal half pale, remainder dark; dorsal surface pale. Mid-femur dark anteriorly except for a few silvery-white scales dorsally at apex; posterior surface pale except for a narrow dorsal dark area on apical half. Hind femur pale, dark dorsally, this dark scaling encroaching onto the anterior and posterior surfaces along apical one-half; a narrow apical band of silvery-white scales anteriorly. Tibiae with posterior surfaces pale-scaled. Tarsi all dark-scaled. Fore and mid-tarsal claws unequal, each claw unidentate; hind tarsal claws equal, simple. *Wings:* Dark-scaled. Halter stem pale, knob with dusky scales. *Abdomen:* Tergites dorsally dark (may be a few median basal yellowish scales on IV–V); a lateral patch of creamy-white scales on I, II–VII with a complete lateral band of brownish-yellow scales, these basally encroaching upon the dorsum on V–VII. Sternite VIII with a dense divided tuft of very long yellow hairs. *Terminalia:* Basistyle broad, short; a dense band of very long setae on tergal surface; a subbasal tuft of short, curved setae on inner tergal surface, some of these setae being distinctively broadened; basad of this tuft and on the inner sternal margin is a small group of setae, 2–3 of these being rather stout; apically on the inner sternal surface is a group of very long setae. Dististyle very distinctive in form; inner surface as figured; outer surface with numerous very short setae and with a large tuft of long setae directed toward base of dististyle (shown by the group of dashed lines in the figure).

FIG. 1. *A.* (*Aedimorphus*) *pampangensis.* Male terminalia (Luzon).

Female. Differs from the male mainly as follows: Proboscis dusky, pale beneath from near base to about the apical one-fourth. Palpi

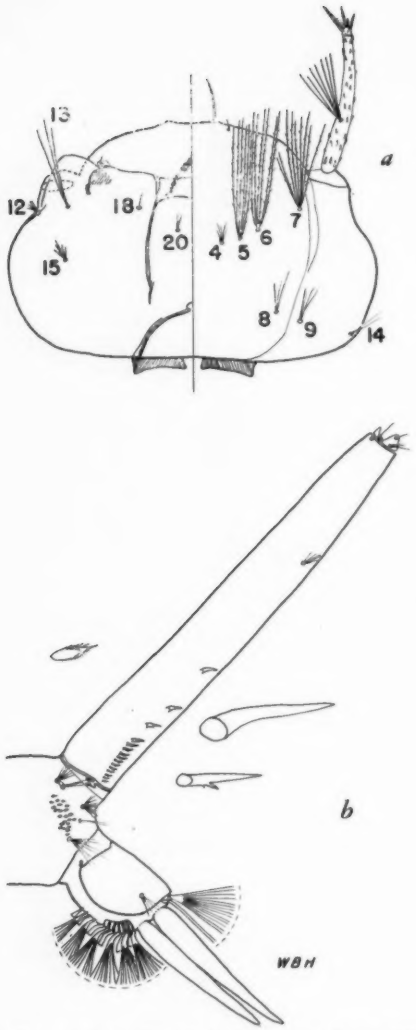

FIG. 2. *A.* (*Aedimorphus*) *pampangensis*. Larva (Mindanao). *a*, Head; *b*, terminal segments.

about one-sixth as long as the proboscis; dusky. Torus with dusky hairs mesally. Vertex with dorsum narrow-scaled, these narrow scales brownish along anterior margin, remainder pale; sometimes a small dark anterior patch of broad dark scales at lateral margin of dorsal narrow scales. Scutellar lobes covered with broad silvery-white scales, some narrow ones may also be present. Postspiracular area with narrow yellowish scales. Fore femur with posterior dark-scaled portion more reduced than in male. Fore and mid tibiae pale except for dorsal surface; hind tibia with a pale longitudinal line on both anterior and posterior surfaces. Tarsal claws equal, fore and mid each unidentate, hind simple. Tergites dorsally dark, IV–VII with an indefinite median brownish-yellow area which may extend the whole width of the segment; the pale lateral areas not encroaching dorsally. Sternites with whitish-yellow scales.

LARVA: *Head:* Antennal shaft with heavy spicules, shaft darkened except for small basal area; antennal hair tuft with 7–13 branches. Mouth brush with comb-like tips. Hair 4 with 5–8 branches, very small; 5 with 6–7; 6 with 4–6; 7 with 7–11; 8 with 2–4; 9 with 3–5; 12 with 5–7; 13 with 2–4; 14 with 1–2; 15 with 5–9; 17 and 18 single, spine-like; 20 with 2–4. Mentum with about 16–17 small lateral teeth. *Thorax:* Prothoracic hair 1 single (considerably longer than 2 or 3); 2 with 2–3 branches; 3 with 3–4. Mesothoracic hair 9 with 8–10 branches; 10 and 12 single; 11 with 1–2, very small. Metathoracic hair 9 with 6–8 branches; 10 single; 11 with 1–2, very small; 12 with 1–2, much smaller than on mesothorax. *Abdomen:* Dorsolateral hair on I with 5–7 branches; on II with 6–7. Lateral hair on I with 3–4; on II and III with 4–7; no distinctly developed lateral hairs on remainder of segments. Pentad hair 1 with 6–8 branches; 2 with 2–4 (on same basal tubercle as hair 1); 3 with 15–20; 4 with 2–4; 5 with 5–9. Comb with about 16–20 small scales in a patch, each scale with base broadly ovoid and spine proper very slender and short, a fringe along most of basal portion of scale. Siphon long, slender, acus present, index about 7.0; 12–18 pecten teeth, the last 2–4 teeth simple and more widely separated from one another, remainder darker and each with 1–2 ventral denticles; siphon hair tuft with 5–7 branches, very small and pale, inserted at apical one-fourth. Anal

plate incomplete, an acus present; *lh* with 2–4 branches, very small and obscure; *isc* with 13–17 branches, about equal to anal plate in length; ventral brush of 12 tufts, all but basal 3–4 arising from a connected barred area, each tuft with 11–15 branches. Anal gills long, lanceolate, dorsal pair slightly longer than ventral pair and about twice as long as anal plate.

BIONOMICS: The adult was not encountered in nature. The larvae were collected from scattered rain pools in a grassy area, from a stream margin containing algae and other vegetation, and from a grassy pool in the bed of a temporary stream.

DISTRIBUTION: *Specimens examined.* U. S. N.M. Luzon: 4 males, 5 females, 8 sets assoc. skins, Olongapo, Subic Bay, Zambales Prov. (Rozeboom, Zolik). One female, 1 assoc. larval skin, 1 larva, Dau, Pampanga Prov. (Cowell, Ingal). One male, 6 females, 4 sets assoc. skins, Quezon City, Manila Prov. (de Guia, Bruce, Baisas). Six males, 26 females, Camp Nichols, Rizal Prov. (Carraway, Callon, Sinclair). Five females, Camp Stotsenberg, Pampanga Prov. Mindanao: 1 larva, San Ramon, City of Zamboanga Prov. (Knight, Laffoon.) One female, Camp Gregg, Pangasinan. Pettit Barracks, Zamboanga, City of Zamboanga Prov. (Visaya.) C.A.S. Mindoro: San Jose (Ross).

Unknown outside the Philippines.

DISCUSSION: As pointed out by Bohart (1945: 63) this species has been confused by various authors with *niveoscutellum* (Theobald) and *alboscutellatus* (Theobald). However, it is separable from the first on details of male terminalia and from the second on the characters given in the key.

Aedes (Aedimorphus) alboscutellatus (Theobald)

Figs. 3, 4

1905. *Lepidotomyia alboscutellata* Theobald, Mus. Nat. Hungarici Ann. 3: 80 (2 females). Type locality: New Guinea. Simbang, Huon Gulf and Friedrich-Wilhelmshafen (Biro). Type: Females (cotypes) in Hungarian National Museum, Budapest.

1907. *Reedomyia alboscutella* Theobald. Theobald, Mon. Cul. 4: 261. Different combination, and lapsus.

1909. *Culex argentinotus* Banks, Philippine Jour. Sci. 4: 547 (male, female). Type locality: Philippines. Pinagsalaan well, Taytay, Rizal Province, Luzon (Banks). Type: Male, female (cotypes) in Bureau of Science, Manila. Probably nonexistent since World War II.

1921. *Aëdes ōmurensis* Yamada, Annot. Zool. Jap. 10: 73 (males, females). Type locality: Japan. Ōmura, Kiushu (Yamada). Type: 2 males, 4 females (cotypes) in Institute for Infectious Diseases, Tokyo.

1922. *Aëdes* (*Ecculex*) *alboscutellatus* Theo. Edwards, Bul. Ent. Res. 13: 101. Synonymy of *ōmurensis*.

1922. *Aedes* (*Ecculex*) *alboscutellatus*, Theobald. Edwards, Indian Jour. Med. Res. 10: 467. Synonymy of *argentinotus*.

Adult described by Barraud (1934: 250) and the larva by Penn (1949: 1).

ADULT: *Male.* Similar to *pampangensis* but differs as follows. *Head:* Proboscis all dark, or with a paler band-like area just beyond the middle, this may be obsolete (except ventrally). Palpi longer than proboscis by slightly more than length of apical segment. *Thorax:* Scutum marked on either side with two small clusters of yellow scales, one on anterior margin and the other on a line with the first and on a level with the scutal angle, a variable amount of yellowish scales may be scattered over the scutum. Scutellum with areas between the lobes free of scales. *Apn* with a few broad silvery scales; *ppn* bare. Propleuron, upper sternopleuron, lower posterior sternopleuron, and upper mesepimeron each with small patch of broad silvery-white scales; a few narrow yellowish scales on the subspira-

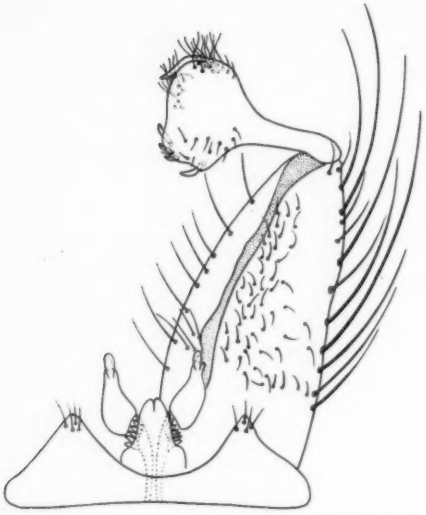

FIG. 3. *A.* (*Aedimorphus*) *alboscutellatus*. Male terminalia (Palawan).

cular area. *Legs:* Femora and tibiae each with apical patch of silvery-white scales anteriorly (that on tibiae is largely dorsal); fore and mid tibiae dark, some pale scaling posteriorly; hind tibia dark posteriorly. *Wing:* Wing with spot of silvery-white scales at base of costal vein. *Abdomen:* Tergite I with lateral band of silvery-white scales; III–VII with basal bands of brownish-yellow scales, VIII largely pale-scaled. Sternites with brownish-yellow scales basally, brown scales apically; VIII covered with silvery-white scales (since this sternite is dorsal on most specimens taken, it creates a very distinctive dorsal abdominal marking), not possessing distinctive hair tufts. *Terminalia:* Basistyle without lobes; tergal surface with numerous very small setae, these not extending to lateral margin setae along distal portion; sternal surface with a regular longitudinal row of very long hairs near to mesal margin. Dististyle distinctively shaped as figured. Ninth tergite strongly concave medially.

Female. Differs from the male mainly as follows. Proboscis dark. Vertex with dorsum narrow-scaled, a median anterior diamond-shaped group of these dusky, the remainder golden; the lateral broad-scaled area creamy-yellow except for dark patch at dorsal margin and sometimes one on a level with *apn*. *Apn* with a few narrow yellowish scales; *ppn* with a few dark narrow scales dorsally. Subspiracular area with a few dusky hairs. Tergites with a basolateral patch of silvery-white scales, the basal bands (which are variable in occurrence and width) either separate from these, or only narrowly connected. Sternites largely covered with brownish-yellow scales, some apical dusky scales usually present.

LARVA: Similar to *pampangensis*, but differing chiefly as follows. Spicules on antennal shaft sparser and not as heavily developed; antennal hair tuft with 5–13 branches. Head hair 5 with 3–4 branches; hair 6 with 3. Mentum with 16–18 lateral teeth. Comb with 20–26 scales in a patch, the scales blunt, fringed laterally and apically and without an enlarged central spine. Siphon index 3.5–3.9, acus large; 18–21 pecten teeth, all with 1–3 ventral denticles, the distal 1–2 teeth more

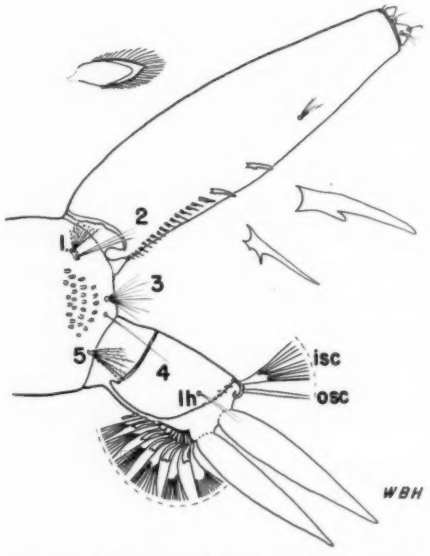

FIG. 4. *A.* (*Aedimorphus*) *alboscutellatus*. Larval terminal segments (Mindoro).

widely spaced. Only 1–2 tufts of ventral brush off the barred area basally.

BIONOMICS: The adults were collected while attempting to bite humans and on several occasions were netted in densely shaded woods. Also, females were taken from a carabao-baited trap. Edwards (1928*a:* 53) reported females taken at a light in Malaya. The larvae were taken on one occasion from road ruts through a coconut grove. Penn (1949: 245) found a larval collection on Mindoro in a shaded permanent ditch in which the water was clear, stagnant, and with a *p*H of 6.5. Leicester (1908: 132) collected the larvae from jungle pools in Malaya.

DISTRIBUTION: *Specimens examined.* U.S. N.M. Samar: 1 female, Osmena (Rozeboom, Zolik). Males, females, San Antonio (Paullus). Palawan: 14 males, 3 females, Bacungan (Laffoon). Seven females, Puerto Princesa (Johnson, Laffoon). Mindanao: 1 male, 2 females, Zamboanga, City of Zamboanga Prov. (Johnson, Laffoon, Knight). One male, Mercedes, Zamboanga Prov. (Laffoon, Knight). Jinamoc Island (between Samar and Leyte) (Medler). C.A.S. Mindoro: 2 larvae, San Jose (Ross).

Literature records. Luzon: Los Banos, Laguna Prov. (Bohart, 1945: 62). Mindoro: Caminawit Point (Penn, 1949: 1). Calapan (Edwards, 1929: 5).

Outside the Philippines, this species has been reported from the Solomon Islands, Admiralty Islands, New Guinea, northern Australia, Duke of York Island, Sumatra, Java, Ceram, Borneo, Malaya, India, Assam, Burma, and Japan.

Aedes (Aedimorphus) mindoroensis Knight and Hull

1929. *A.* (*Aed*) *lowisi* Theo. Edwards, Notulae Ent. 9: 5.

1934. *Aëdes* (*Aëdimorphus*) sp. Edwards, footnote, in Barraud, Fauna Brit. India, Dipt. 5: 250. Called attention to the fact that material named as *lowisi* by Edwards (1929: 5) in actuality represented another species.

1951. *Aedes* (*Aedimorphus*) *mindoroensis* Knight and Hull, Pacific Sci. 5: 199 (1 male, 4 females). Type locality: Philippines. Calapan, Mindoro Island. Type: Male (holotype) in B.M.† Terminalia separated.

DISTRIBUTION: *Specimens examined.* Type series. Mindoro: Calapan.

DISCUSSION: *A. mindoroensis* is most closely related to *lowisi*, a species that is known only from the Andaman Islands and from Morotai in the Moluccas. Externally, the adult of *lowisi* is indistinguishable from that of *mindoroensis*. However, the male genitalia of *lowisi* differs in having the narrow basal portion of the dististyle equal to no more than half the total length and in being evenly slender instead of rather broadly tapered, in having the short tergal setae in a rather narrow band along the mesal margin, and in lacking any special arrangement of the sternal setae of the basistyle. Because of the nature of the similarities between these species, it seems likely that a single polytypic species is concerned. However, much more material must become available before this can be determined definitely.

This species may be distinguished from the other members of Group C occurring in the Philippines by its banded tarsi.

Aedes (Aedimorphus) punctifemore (Ludlow)

Fig. 5

1921. *Stegomyia punctifemore* Ludlow, Military Surgeon 49: 690 (1 female). Type locality: Philippines. Fort Wm. McKinley, Rizal Prov., Luzon. Type: Female (holotype) in U.S.N.M.†

Male described by Dyar (1925: 217) and the female by Edwards, in Barraud (1934: 443).

ADULT: Scutum with several small spots of broad silvery scales. Tarsi all dark.

Male. A poor terminalia mount in the U. S. National Museum is the only existing spec-

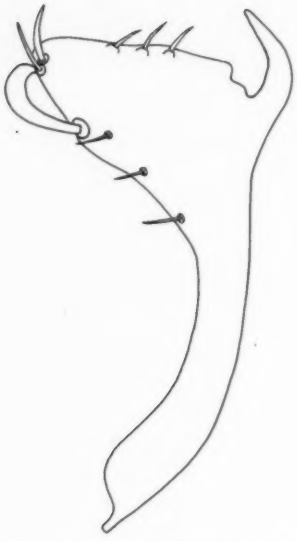

FIG. 5. *A.* (*Aedimorphus*) *punctifemore*. Dististyle of male terminalia (Luzon).

imen at present known of the male of this species. Figure 5 illustrates the dististyle of this specimen.

Female. Wing length about 3.5 mm. Proboscis dark, paler beneath. Palpus about one-sixth as long as the proboscis, dark. Torus with broad silvery scales medially. Vertex with some broad dark scales medially, narrow white scales medially on nape, maybe a few medial dark narrow scales, and in the type these latter scales extend to the eyes; remainder of dorsum and all of lateral surface broad-scaled, pale except for two dark-scaled areas; some dark upright-forked scales on nape. *Thorax:* Integument dark. Scutum with fine reddish-black scales, 2 pairs of small silvery broad-scaled spots on disc of scutum, a small patch of similar scales above wing base, one on either side of prescutellar space and one on prescutellar space. Scutellum with broad white scales on each lobe. *Apn* with some broad white scales; *ppn* with narrow dark ones above, some white broad scales below. Following pleural areas each with a patch of small white broad scales: propleural, subspiracular (2 patches), paratergite, dorsosternopleural, lower posterior sternopleural, and mesepimeral. *Legs:* Femora and tibiae anteriorly dark, with silvery anterior knee spots and with scattered broad translucent silvery scales present. Tarsi dark. *Wings:* Dark, a small white spot basally on costa. Halter knob dark. *Abdomen:* Tergites dark, basolateral white spots present.

LARVA: Unknown.

BIONOMICS: Unknown except that females were taken in a carabao-baited trap on Samar.

DISTRIBUTION: *Specimens examined.* R.K.L. Samar: Numerous females, Osmena. U. S. N.M. Luzon: 1 male terminalia, 15 females, Camp Nichols, Rizal Prov. (Carraway.) Female type, Ft. Wm. McKinley, Rizal Prov.

Outside the Philippines, known only from Bihar, India.

Aedes (Aedimorphus) vexans nocturnus (Theobald)

Figs. 6, 7

1903. *Culex nocturnus* Theobald, Mon. Cul. 3: 159 (females). Type locality: Fiji (Hall). Type: 2 females (cotypes) in B.M.†

1913. *Culex nocturnus niger* Theobald, Nova Caledonia 1: 164 (1 specimen). Type locality: New Caledonia. Canala (Sarasin and Roux). Type: Sex unknown; in Bale Museum.

1946. *Aedes* (*Aedimorphus*) *vexans nocturnus* (Theobald). Bohart and Ingram, Mosq. Okinawa and Islands in Central Pacific, NavMed. 1055, p. 15.

ADULT: Vertex dorsum and scutellum narrow-scaled. Scutum with bronzy-brown, yellow, and whitish scales intermixed. Hind tarsi with basal bands on all segments.

Male. Wing length 3.0–3.4 mm. *Head:* Proboscis dark, a poorly defined broad paler area near the middle. Palpus longer than proboscis by about length of last segment; II–IV with basal white bands; numerous long hairs arising apically on III and laterally along IV–V

(these two segments being down-tilted). Torus bare. Vertex dorsum covered with narrow and narrow-curved pale scales and dusky and pale upright-forked scales, lateral portion covered with broad pale scales, sometimes an anterior spot of dusky broad scales at the margin of the narrow-scaled area. *Thorax:* Scutum covered with an indefinite pattern of narrow bronzy-brown, yellow, and whitish scales. Scutellum with pale narrow scales. *Apn* and *ppn* with narrow and narrow-curved scales, pale (the dorsal scales on *ppn* are frequently brownish, however). The following pleural areas each with a patch of broad pale scales: propleural, subspiracular (2 patches), postspiracular, paratergite, dorsal sternopleural, medio-posterior sternopleural, and mesepimeral; usually a very few scales on the prealar knob, particularly in female. *Legs:* Femora speckled with pale scales anteriorly, knee spots present. Tibiae may have some scattered pale scales anteriorly, apical pale scaling present on fore and hind, basal pale scaling present at least ventrally on all the tibiae. Fore and mid-tarsi with first two or three segments with basal pale bands (may be none on I of fore tarsus). Hind tarsi with basal pale bands on I–V. Fore and mid-tarsal claws unequal, each unidentate; hind claws equal, simple. *Wings:* Dark-scaled, a small basal spot of pale scales may be present on the costa. *Abdomen:* Tergite I with a lateral band of pale scales, II–VII with basal bands, those on the more posterior segments prolonged laterally. Sternites largely pale-scaled, dark scaling may be present medially. *Terminalia:* Basistyle with a basal setose plaque on mesal membranous surface; a rather regular longitudinal row of stout bristles on the sternal surface near the mesal margin. Dististyle with appendage distinctly subapical. Ninth tergite concave medially.

Female. Length of wing about 3.5 mm. Torus with a patch of pale scales medially. Differs from male chiefly as follows: Palpus approximately one-fifth as long as the proboscis, apex pale-scaled, may be a few pale scales medially. Proboscis with pale area larger and more pronounced. Mid-tarsus with basal pale bands on I–IV, I with some pale scales medially. Tarsal claws equal, fore and mid each unidentate, the hind simple. One or more of tergites IV–VII with apical pale scaling, I–VII with lateral pale bands that are separate from the basal bands. Wing as in male, or sometimes possessing considerable pale scaling along costa and subcosta and even some pale scales on vein 1.

FIG. 6. *A.* (*Aedimorphus*) *vexans nocturnus.* Male terminalia (Samar).

LARVA: *Head:* Antenna spiculated, tapering slightly from base to apex; antennal hair tuft with 6–10 branches, inserted at about basal one-third. Mouth brushes with comb-like tips. Hair 4 very small, with 2–6 branches; 5 single or double (rarely triple); 6 single (sometimes double); 7 with 5–12; 8 single; 9 with 1–3; 12 with 5–10; 13 with 1–3; 14 with 1–3; 15 with 3–8; 17 and 18 single, 18 occasionally forked; 20 with 3–8. Mentum with 11–16 lateral teeth. *Thorax:* Prothoracic hairs 1 and 2 single; 3 with 2–4 branches. Mesothoracic hair 9 with 5–9 branches; 10 and

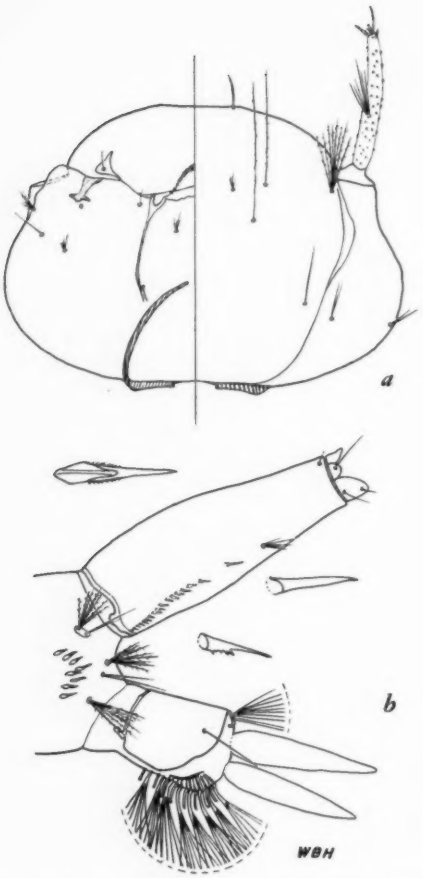

FIG. 7. *A.* (*Aedimorphus*) *vexans nocturnus*. Larva (Samar). *a*, Head; *b*, terminal segments.

12 single, stout; hair 11 very small, with 1–3; a short acutely tapered spine at base of tubercle. Metathoracic hair 9 with 4–6 branches; 10 single, stout; 12 single, much reduced; 11 very small, with 1–5. *Abdomen:* Dorsolateral hair on I with 3–8 branches; on II with 3–6. Lateral hairs on I and II with 2–4; on III–V with 1–4; on VI with 1–3. Pentad hair 1 with 5–11 branches; 2 and 4 with 1–3; 3 with 5–9; 5 with 6–10. Comb with 8–10 teeth, long, acutely tapered, with attached portion oval in shape and fringed laterally. Siphon smooth with a narrowly attached acus, index 2.1–3.2; 13–19 pecten teeth in a row, the distal two more widely separated, each tooth except the distal two or three with 1–3 ventral denticles; siphon hair tuft with 3–7 branches. Anal plate incomplete, smooth, with an attached acus; *lh* small, single or double; *isc* with 6–9 branches, *osc* single; ventral brush of 16 (rarely 15–18) tufts with 3 or 4 off the barred area basally, elements of barred area joined laterally by a bar, tufts of ventral brush with 4–11 branches. Anal gills subequal, narrow and gradually tapering to apex, or broad at base and rapidly tapering to apex; 1.7 to 2.4 times longer than anal plate.

BIONOMICS: The adults were commonly collected while trying to bite humans at night, and from a light trap. The larvae were frequently encountered in temporary rain-filled ground pools and depressions of all types, but principally from those in grassy areas.

DISTRIBUTION: *Specimens examined.* R.K.L. Luzon: Olongapo, Subic Bay, Zambales Prov. (Rozeboom, Zolik, McMillan). Samar: Osmena (Laffoon, Rozeboom). Palawan: Iwahig Penal Colony, Puerto Princesa, Bacungan, Tacburos, and Balsahen River (Johnson, Laffoon, Fitzgerald). Mindanao: Zamboanga and San Ramon (Johnson, Knight, Laffoon). C. C. Luzon: Sison, Pangasinan Prov. (Francle-mont). Baisas Coll. Luzon: Tunkong Manga, Bulacan Prov. Colo. State U. Coll. Mindoro: San Jose. (Howe.)

Literature records. Mindoro: Caminawit Point (Penn, 1948: 245). Tunkulan (Edwards, 1929: 5). Luzon: Manila (Edwards, 1929: 5).

Outside the Philippines, this subspecies is known from Samoa, Tonga, Fiji, New Hebrides, New Caledonia, Australia, New Guinea, Marshalls, Marianas, and Netherlands Indies.

DISCUSSION: Bohart and Ingram (1946: 15) resurrected the name *nocturnus* for the *vexans* of the Australasian region and of the Philippines. They consider the material known to date from these areas to be subspecifically

distinct on the basis of larval head hairs 5 and 6, which are single to triple and single, respectively. Typical *vexans* larvae have these hairs with 3–5 and 2–4 branches (the latter occasionally single). Philippine larvae seen by us have hair 5 single or double (rarely triple) and 6 single (sometimes double). Consequently, the name *nocturnus* is employed in this paper. Larvae from Europe (Edwards, in Barraud, 1934: 253), Japan (La Casse and Yamaguti, 1948: 102), and the United States (Carpenter, Middlekauff, and Chamberlain, 1946: 232) have the hair branching given above for typical *vexans*.

The two cotype females of *nocturnus* were compared in the British Museum with the types (all females) of *eruthrosops* Theobald (Ceylon), *minuta* Theobald (India), and *nipponii* Theobald (Japan). The only difference noted was that in *nocturnus* the wings are dark except for a small basal patch of pale scales on the costa. In the other three types, the wings possess a variable amount of scattered pale scaling along the costa (as is frequently the case in Philippine material).

Edwards (in Barraud, 1934: 253) gives evidence that indicates the probable occurrence of additional races or subspecies, but, until much more work is done on this subject, the status of the Philippine material cannot be further clarified.

Aedes (Aedimorphus) ostentatio (Leicester)

1908. *Aioretomyia Ostentatio* Leicester, Cul. Malaya, p. 193 (females). Type locality: Malaya. Pahang road (at 4½ miles) and Gombak road (at 5 miles), Kuala Lumpur (Leicester). Type: 2 females (cotypes) in B.M.†

1910. *Pseudohowardina chrysoscuta* Theobald, Mon. Cul. 5: 228 (female). Type locality: Ceylon. Peradeniya (Green). Type: Female (holotype) in B.M.†

1911. *Danielsea pagei* Ludlow, Psyche 18: 128 (7 females). Type locality: Philippines. Fort Pikit, Mindanao (Page). Type: 7 females (cotypes) in U.S.N.M.† One of these specimens here designated lectotype.

1913. *Ochlerotatus ostentatio* (Leicester). Edwards, Bul. Ent. Res. 4: 228. Synonymy of *chrysoscuta*.

1922. *Aedes ? ostentatio* Leic. Edwards, Indian Jour. Med. Res. 10: 468. Synonymy of *pagei*.

1925. *Aëdes* (*Aëdes*) *ostentatio* Leicester. Dyar and Shannon, Insecutor Inscitiae Menstruus 13: 78. Different combination.

1928. *Aedes* (*?Aedimorphus*) *ostentatio* (Leic.). Barraud, Indian Jour. Med. Res. 16: 374. Different combination.

Female described by Barraud (1934: 267).

ADULT: Vertex dorsum partially broad-scaled. Scutellum narrow-scaled. Scutum with narrow lines of yellow scaling. Tarsi all dark.

Male. Unknown.

Female. Wing length 3.6 mm. *Head:* Proboscis dark-scaled. Palpus only about one-sixth length of proboscis, dark-scaled. Torus ochreous, with a few fine dark scales and hairs medially. Vertex dorsum with broad dark scales, a line of narrow golden scales along eye margins and a patch of similar scales medially on nape (this narrowing a variable distance anteriorly, reaching anterior margin in some specimens), a patch of upright-forked dusky to golden-colored scales on nape; lateral portion with yellowish broad scales, a median patch of broad dark scales. *Thorax:* Scutum with narrow yellow scales along lateral (broken in region over paratergite) and anterior margins and along scutal angles, a narrow median longitudinal band of yellow scales that forks at the prescutellar area, remainder with dark narrow scales; acrostichal bristles absent, dorsocentral bristles present. Scutellar lobes with narrow yellow scales, sometimes a few median narrow dark scales on mid-lobe. *Apn* with a few dark scales above and a patch of narrow yellow scales below, *ppn* bare except for a sparse dorsal line of

narrow dark scaling. Each of the following pleural areas with a patch of broad pale scales: propleural, postspiracular (few or none), paratergite (few or none), dorsal sternopleural, ventroposterior sternopleural, and mesepimeral. *Legs:* Fore and mid-femora dark anteriorly, hind with anterior surface pale except for apical fourth and most of dorsal margin, a line of pale scales anteriorly on apex of hind and mid femur. Tibiae and tarsi dark. Tarsal claws equal, fore and mid unidentate, hind simple. *Wings:* Dark-scaled. Halter knob with dusky scaling. *Abdomen:* Tergites dorsally dark, basolateral pale scaling on I–VII, this visible dorsally on II–VI. Sternites III–VII with basal pale bands.

LARVA: Undescribed.

BIONOMICS: The single adult from Palawan was netted in a densely shaded area near a river. No larvae were found in the Philippines. Leicester (1908: 193) collected larvae from jungle pools in Malaya. Further, he reported the female to be a vicious daytime biter.

DISTRIBUTION: *Specimens examined.* R.K.L. Palawan: 1 female, Bacungan (Laffoon). C.A.S. Mindoro: 3 females, San Jose (Ross).

Literature records. Mindanao: Ft. Pikit (type series of *pagei*).

Outside the Philippines, reported from India, Ceylon, Malaya, Indo-China, Sumatra, Java, Borneo, and Ceram.

DISCUSSION: The Palawan female was compared with Leicester's two cotype females in the British Museum. It was found to agree sufficiently well to be considered conspecific.

Theobald's type female of *chrysoscuta* was examined and found to agree well with the Palawan specimen except that the pleurae are noticeably paler in color.

Aedes (Aedimorphus) wainwrighti
Baisas

1946. *Aedes* (*Aedimorphus*) *wainwrighti* Baisas, Philippine Mon. Bul. Bur. Health 22: 34 (1 female). Type locality: Philippines. Llavac, Infanta, Tayabas Prov. Luzon (Sunico). Type: Female (holotype) in Philippine Bureau of Science, Manila.

ADULT: A dark-brown species, with a broad median silvery line on anterior half of scutum, broad silvery scales on the paratergite, midscutellar lobe, and torus. Hind tarsi banded with white.

Male. Unknown.

Female. Modified from the original description. *Head:* Proboscis dark brown, nearly as long as fore femur. Palpus about one-sixth length of proboscis, dark brown. Torus dark brown, with a small patch of broad silvery scales medially. Vertex broad-scaled, a triangular silvery patch medially that broadens anteriorly and extends on either side as a short fine line along the eyes, laterad to this median area is a dark-scaled spot, the remainder of the dorsal surface and the entire lateral surface pale brownish (almost whitish under different lighting), a median area of narrow dark scales and a few upright-forked dark scales on the nape. *Thorax:* Integument brownish on scutum, darker on pleurae. Scutal scales narrow dark brown; a broad median silvery line on the anterior half of the scutum; a pair of dorsocentral bristles anteriorly and a stronger pair above level of wing bases, two pairs of prescutellars, rather few supra-alars. Scutellum with broad scales, silvery on mid-lobe except for a narrow dark line on posterior margin, dark on lateral lobes. *Apn* with a small patch of silvery flat scales; *ppn* without scales, 3 bristles present. Each of the following pleural areas with a patch of broad silvery scales: propleural, subspiracular, paratergite (covering entire area), upper sternopleural, mediposterior sternopleural, and upper mesepimeral. *Legs:* Dark brown. Femora pale basally and below, hind with basal half pale both anteriorly and posteriorly, mid and hind with a conspicuous silvery spot at apex. Fore and mid-tarsi with a basal white band on I, remainder dark. Hind tarsus with a basal white band on I, remainder missing. *Wings:* Dark.

Abdomen: Tergites dark dorsally, silvery lateral patches visible above on V–VII: lateral margin of I entirely silvery, of II–VII broadly white basally. Sternites II–VII basally pale, apically dark, segment VIII retractile and hidden in VII.

LARVA: Unknown.

BIONOMICS: The single known specimen was taken in a mosquito trap.

DISTRIBUTION: Known only from the single type specimen. Luzon: Llavac, Infanta, Tayabas Prov.

DISCUSSION: As Baisas pointed out in the type discussion, this species has a strong resemblance to members of Group E (*albolineatus*-group) of *Stegomyia* but is separable from them on the possession of paratergite scaling and in being brownish rather than black in general appearance.

In a footnote to the type description, Baisas stated that, subsequent to the preparation of the description, two males and several females of a closely similar species were received from Mt. Apo, Davao, Mindanao (Hoogstraal). In these, the hind tarsi had I with basal one-fifth white, II with the basal one-third white, III all white except for a narrow ring at apex, IV–V all dark (paler under certain lights). The male palpi were slender throughout, without hairs, and upturned apically. The male terminalia was that of an *Aedimorphus*.

Until the male terminalia of these species are available for study, it will not be definitely possible to place them, but from the available information it seems likely that they represent a separate group near Group A (*apicoannulatus*-group). This group is unusual in that the included species are all tree-hole breeders.

Subgenus BANKSINELLA Theobald

1907. *Banksinella* Theobald, Mon. Cul. 4: 468. Genotype: *luteolateralis* Theobald (Africa).

ADULT: Male palpi longer than proboscis by one-half or more of segment IV; segment V so reduced as to appear absent, segment IV strongly upturned, numerous ventrally directed long hairs arising apically on III and all along IV. Vertex dorsum and scutellum narrow-scaled. Dorsocentral and acrostichal bristles present (sparse and short). Paratergite bare. Lower mesepimeral bristles present or absent. Fore and mid-tarsal claws of male unequal, each unidentate; hind equal, unidentate or simple. Tarsal claws of female equal, each unidentate, hind simple in *lineatopennis*. *Terminalia:* Basistyle with a distinct basal lobe. Dististyle inserted subterminally, with or without articulated appendage. Claspettes absent. Mesosome divided into lateral plates, each of which are crenulated or toothed laterally.

LARVA: Similar to *Aedimorphus* in having the distal pecten teeth more widely spaced but differing in lacking an acus on the anal plate. Antennal hair tuft with 8–11 branches. Head hair 4 with 5–9 branches; 5 with 4–7; 6 with 3–6. Comb with 6–12 large teeth in an irregular row, each tooth with a sharp spine and basal fringe. Siphon with an attached acus; 12–24 pecten teeth, each with 1 or 2 strong basal denticles except for the distal 2–3 which may be simple, these latter more widely spaced. Anal plate complete, or narrowly incomplete; ventral brush of 12–16 tufts, basal 3–7 tufts off the barred area. Habitat chiefly rain-filled temporary pools.

DISTRIBUTION: Two species, *brugi* Edwards and *imprimens* Walker, are Australasian, with the latter also occurring in the Philippines. One species, *lineatopennis* (Ludlow), extends from the Ethiopian region into the Australasian and Oriental regions. The remaining species are Ethiopian.

SYSTEMATICS: Closely related to the subgenus *Aedimorphus*, differing most markedly in the structure of the male palpi.

Aedes (Banksinella) imprimens (Walker)

Figs. 8, 9

1861. *Culex imprimens* Walker, Linn. Soc. Lon-

don, Proc. 5: 144. 1860 (female). Type locality: Amboina (Wallace). Type: Female (holotype) in B.M.† Identified as type by E. A. Waterhouse.

1901. *Culex imprimiens*, Walker. Theobald, Mon. Cul. 1: 422. Lapsus.

1908. *Culex Auratus* Leicester (nec Grabham, 1906), Cul. Malaya, p. 153 (female). Type locality: Malaya. Type: No information. Not in B.M.

1913. *Ochlerotatus imprimens* (Walker). Edwards, Bul. Ent. Res. 4: 228. In part. Questioned synonymy of *auratus* (no material seen). Different combination.

1946. *Aedes* (*Banksinella*) *imprimens* (Walker). Hsiao and Bohart, Mosq. Japan, Nav-Med 1095, p. 22. Different combination.

Larva is described by Bohart (1945: 63); systematics treated by Edwards, in Barraud (1934: 257) and Hsiao and Bohart (1946: 22).

ADULT: A large yellowish-brown species. Hind tarsal segments all basally banded.

Male. Wing length about 5.0 mm. *Head:* Proboscis dark-scaled. Palpus longer than proboscis by over one-half length of terminal long segment, dark-scaled. Torus bare. Vertex dorsum with narrow golden scales, dark upright-forked scales posteriorly and pale ones anteriorly; lateral portion of vertex with broad pale scales. *Thorax:* Scutum brown, rather thinly covered with hair-like brownish-gold scales, paler over wing bases, and on prescutellar area. All scutellar lobes with narrow yellow scales. *Apn* with broadened and narrow yellow scales; *ppn* with narrow yellow scales. Each of the following pleural areas with a patch of broadened whitish scales: subspiracular, dorsal sternopleural, ventroposterior sternopleural, and mesepimeral (pin through postspiracular area). *Legs:* Fore and mid-femora dark anteriorly, some scattered pale scales ventrally, and pale scales at apices; hind femur pale-scaled anteriorly except for a dark apical area, dark scales on dorsal surface, a ring of pale scales on extreme apex anteriorly. Tibiae dark. Fore tarsi dark except for a few pale scales basally on II; mid-tarsi with narrow basal pale bands on I–II; hind tarsi with narrow basal pale bands on I–V, broadest on I and narrower on each succeeding segment. Fore and mid-tarsal claws unequal, each unidentate; hind tarsal claws equal, each unidentate. *Wings:* Dark-scaled, wing membrane with a pronounced yellowish iridescence. Halter knob dark. *Abdomen:* Tergites dark, lateral margin of I with a band of pale scales, III–VII with narrow basal ochreous bands. Sternites pale-scaled, an apical line of dark scales on most of them. *Terminalia:* Drawing and description from a New Guinea specimen. Basistyle short, broad; a prominent subbasal lobe present, this bearing numerous very stout setae. Dististyle broad, deeply divided apically into a pair of unequal arms, the shorter of these bearing several setae. Ninth tergite broadly divided medially.

FIG. 8. *A.* (*Banksinella*) *imprimens* (Dutch New Guinea). Male terminalia (Dutch New Guinea). Paraproct omitted on right.

Female. Similar to the male but differing as follows. Palpus approximately one-fifth as long as proboscis, dark. Torus with a few dark hairs and scales medially. Vertex with a medioanterior area of dark narrow scales and with a patch of broad dark scales at lateral margin of dorsal narrow-scaled area. Scutum with a

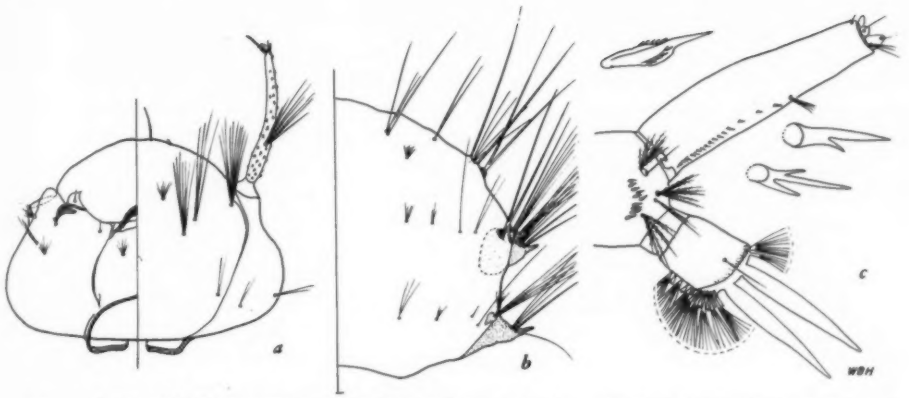

FIG. 9. *A.* (*Banksinella*) *imprimens.* Larva (Dutch New Guinea). *a*, Head; *b*, thorax, dorsal aspect; *c*, terminal segments.

variegated pattern of blackish-brown and golden scales. *Ppn* with some dark scales interspersed dorsoanteriorly. Propleuron and postspiracular area also each with a scale patch. Fore and mid-tarsi with small basal white patches on I–III, hind tarsi as in male. Tarsal claws equal, unidentate. Base of costa with a few pale scales. Tergites II–V with basal ochreous bands, a dorsobasal median pale patch on VI, nearly complete lateral ochreous bands on I–VII.

LARVA: Description based on a whole larva from Toem (E. S. Ross), and a larval skin from Hollandia, both of Dutch New Guinea, and a whole larva and larval skin from Bougainville, Solomon Is. (A. B. Gurney), all of which are in the U.S.N.M. No larval specimens from P. I. available. *Head:* Integument with a fine droplet-like rugosity. Antenna largest at base and tapering slightly toward apex, with prominent spicules over most of length; antennal hair tuft with 8–11 branches. Hair 4 with 7–9 branches; 5 with 4–7; 6 with 3–5; 7 with 9–13; 8 double (once single); 9 with 2–3; 12 with 8–10; 13 and 14 with 2–3; 15 with 5–8; 17 and 18 single (rarely forked at tip); 20 with 5–9. Mentum with 20–24 lateral teeth. *Thorax:* Meso- and metathoracic 9–12 hair groups arising from large heavily sclerotized tubercles, each tubercle also bearing a strong blunt spine; mesothoracic hair 9 with 6–7 branches. *Abdomen:* Dorsolateral hair on I with 3–6 branches; on II with 4–5. Lateral hair on I with 2–3; on II with 4–6; on III with 5; on IV–VI with 2–4. Pentad hair 1 with 7–13 branches; 2 with 1–2; 3 with 6–11; 4 with 2–3; 5 with 5–11. Comb with 10–12 teeth in an irregular row, each tooth large with a sharp spine and lateral fringe on the attached portion. Siphon brown, acus attached, index 3.2–3.5; 19–24 pecten teeth, each with 1–2 strong basal denticles except the distal 2–3 which are simple, these latter teeth more widely spaced; siphon hair tuft moderate, with 4–7 branches. Anal plate complete, with a number of short acutely tapered spicules along dorsolateral margin (one specimen also had a small round detached acus); *lh* single (once double), shorter than length of anal plate; *isc* with 7–11 branches; *osc* with 3–5 branches. Ventral brush of 16–17 tufts, basal 4–7 tufts off barred area and piercing anal plate, barred area not connected laterally. Anal gills (one specimen) subequal, dorsal pair 2.3 times longer than anal plate.

BIONOMICS: No specimens were collected by us in the Philippines. However, females were collected in New Guinea and the Solomons while attempting to bite humans. A single male was netted in deep jungle in New

Guinea. The females are vicious biters and are present in great numbers shortly after the beginning of isolated rainy periods. Gurney (Bohart, 1945: 63) collected larvae on Bougainville Island from shaded leafy woodland pools. Causey (1937: 413) reported larvae from a buffalo wallow in Siam. Dr. E. S. Ross has reported to us in personal correspondence that he collected the larvae on Mindoro in shaded temporary puddles.

DISTRIBUTION: *Specimens examined.* U.S. N.M. Palawan: 4 females, Puerto Princesa (McGregor). Mindanao: 1 female, Ft. Pikit (Spry).

Literature records. Mindanao: Port Banga (Edwards, 1929: 5).

Also, the above unpublished record from Dr. E. S. Ross of San Jose, Mindoro.

Outside the Philippines reported from Japan, Siam, ? Malaya, Sumatra, Java, Borneo, Ceram, Amboina, New Britain, New Guinea, and the Solomons.

DISCUSSION: The type has been studied in detail. The head and hind tarsal segments III–V are completely missing, and the scutum is rather badly rubbed. The remainder of the specimen is in sufficiently good condition to make out all the characters. A female specimen from Cyclops Mts., Hollandia, Dutch New Guinea (Laffoon) in the Knight collection was compared with the type and found to agree in all details. A male which was captured at the same time as this female, and which agrees very well with it, is believed to represent the male of *imprimens*. This pair of specimens was used for the above adult description. Three wild-captured females from Pavuvu, Russell Group (Downs) and one from Guadalcanal (Downs) in the Knight collection agree in all details with the New Guinea female.

The larva has not previously been described except for some brief notes by Bohart (1945: 63) from larvae taken on Bougainville Island, Solomons (Gurney).

Apparently, no authentic material of *auratus* Leicester exists, but based on Leicester's description (female only) this species agrees very well with the description of *imprimens* given above.

The Dutch New Guinea male specimen referred to previously was compared to the type (male) of *A.* (*B.*) *brugi* Edwards in the British Museum. The two were found identical in all details, including terminalia, except that the *brugi* specimen was distinctly smaller (wing length described as 3.8 mm. in original description). This is also true of a single male in the Knight collection that was reared from larvae collected in a road rut at Lake Sentani, Hollandia, Dutch New Guinea. This specimen was also compared to the type of *brugi* and found to agree perfectly. It is believed that *brugi* is a synonym of *imprimens*, but, until evidence is forthcoming that the size difference is inconsequential, it is thought better to hold the two species separate.

Aedes (Banksinella) lineatopennis (Ludlow)

Figs. 10, 11

1901. *Culex luteolateralis* Theobald (type male only), Mon. Cul. 2: 71 (males, females). Type locality: Africa. Durban, Natal (Christophers). Salisbury, Rhodesia (Marshall). Malaya. Straits Settlements, Perak (Wray). Type: Male (lectotype) in B.M.

1905. *Taeniorhynchus lineatopennis* Ludlow, Canad. Ent. 37: 133 (females). Type locality: Philippines. Camp Gregg, Bayambang, Pangasinan Prov. Luzon (Chamberlain). (However, the type label has "Camp Gregg, Angeles, Pampanga Province.") Type: 3 females (cotypes) in U.S.N.M.† The specimen bearing the locality label is here designated lectotype.

1913. *Pseudohowardina linealis* Taylor, Rpt. 1911, Austral. Inst. Trop. Med., p. 10 (female). Type locality: Australia. Ching Do and Townsville, Queensland. Type: No information.

1915. *Banksinella lineatopennis*, Ludlow. Edwards, Bul. Ent. Res. 5: 274. Different combination. Restricted *luteolateralis* to type female and applied *lineatopennis* to type male.

Adult and larvae described by Barraud (1934: 269).

ADULT: A small dark species readily recognized by the broad longitudinal lateral area of yellow scaling on the scutum.

Male. Wing length about 2.6 mm. *Head:* Proboscis dark. Palpus longer than proboscis by nearly the length of the terminal segment; dark. Vertex dorsum with a large central area of yellow narrow and upright-forked scales. *Thorax:* Scutum with a broad area of yellow scales along the lateral margin, central portion dark-scaled, some dark scales present beyond the yellow scales on the lateral margin over the spiracle; dorsocentral, acrostichal, and prescutellar bristles present. Mid-scutellar lobe with narrow yellow scales, sometimes a few dusky scales apically; lateral lobes essentially bare of scales. *Apn* bare of scales; *ppn* with a few narrow dark scales. Pleuron nearly bare of scales, a few usually being present on the propleuron, dorsally and medioposteriorly on the sternopleuron, and on the mesepimeron; 1–2 lower mesepimeral bristles present. *Legs:* All dark. Fore and mid-tarsal claws unequal, each unidentate; hind claws equal, simple. *Wings:* Dark, pale scales along vein 1 to junction with stem of vein 2 and along basal portion of vein 5. *Abdomen:* Tergite I dark-scaled dorsally; II–VII with dorsal basal pale bands. Sternites dark. *Terminalia:* Basistyle elongate; with numerous hairs along inner surface, a row of short peg-like setae interspersed among these apically; with a projecting basal lobe that bears several strong apical spines. Dististyle inserted before apex, prominently widened just beyond middle. Ninth tergite deeply concave medially.

Female. Differs from male chiefly as follows. Palpus approximately one-seventh as long as the proboscis. Scutum with dark scales laterad of the yellow-scaled band from the anterior margin to the level of the wing base. Lateral scutellar lobes with a few narrow yellow scales. Tarsal claws equal, unidentate on fore and midlegs, simple on hind. Some of the sternite scaling appearing paler. Wing with almost all of veins Sc and 5 pale-scaled also, some pale scales may be present basally on vein 4.

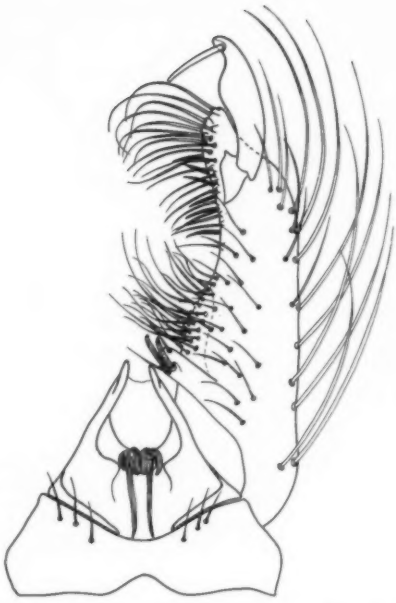

FIG. 10. *A.* (*Banksinella*) *lineatopennis*. Male terminalia (Samar).

LARVA: *Head:* Antenna stocky, broadest at base and tapering somewhat toward apex; prominent spicules over most of length; antennal hair tuft with 5–10 branches, inserted before middle. Mouth brushes with comblike tips. Hair 4 small, with 5–9 branches; 5 with 4–7; 6 with 3–6; 7 with 8–13; 8 with 2–3; 9 with 1–5, usually 3–4; 12 with 4–7; 13 and 14 with 2–5; 15 with 5–10; 17 and 18 usually single, occasionally double; 20 with 6–10. Mentum with 17–20 lateral teeth. *Thorax:* Prothoracic hair 1 single or double; 2 stalked, with 1–3 branches; 3 stalked, with 2–5; the whole group small in size. Meso-

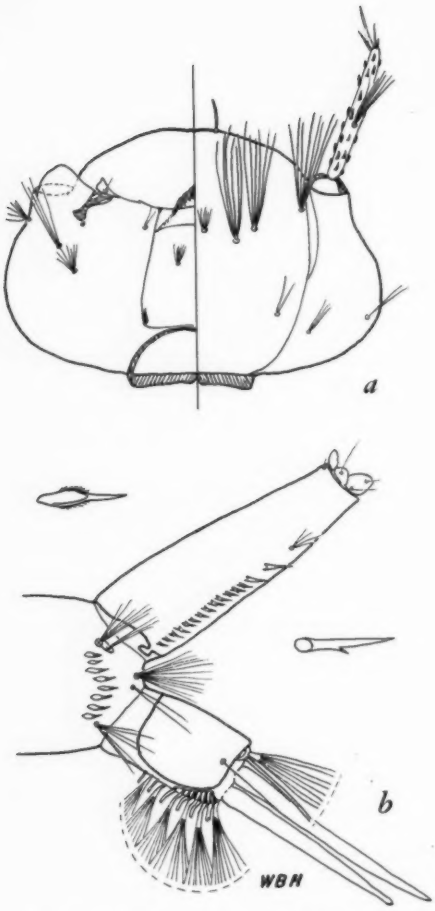

FIG. 11. *A.* (*Banksinella*) *lineatopennis*. Larva (Samar). *a*, Head; *b*, terminal segments.

thoracic hair 9 with 6–10 stout branches; 10 and 12 single, stout; 11 not seen. Metathoracic hair 9 with 3–4; 10 single; 12 much reduced, with 1–2; 11 not seen. *Abdomen:* Dorsolateral hairs on I and II with 2–4 branches. Lateral hair on I single or double; on II with 2–7; on III–VI single, rarely with 2–3. Pentad hair 1 with 4–8 branches; 2 and 4 with 2–3; 3 with 8–11; 5 with 4–9. Comb with 6–8 (usually 8) teeth, long, acutely tapering, attached portion oval with lateral fringe. Siphon smooth with a narrowly attached acus, index 2.1–2.5; 12–16 pecten teeth in a straight row, the distal two or three more widely spaced, the teeth usually with just one ventral denticle; siphon hair tuft with 2–7 branches, the tuft no longer than the distal pecten tooth. Anal plate incomplete, smooth; *lh* single or double; *isc* with 8–15, *osc* single; ventral brush of 12 tufts with 3–5 off the barred area basally, the tufts with 4–12 branches. Anal gills subequal, narrow, tapering to a slender point, 2.7–3.0 times longer than the anal plate.

BIONOMICS: The adults were taken in light traps. Nine larval collections were made, all in temporary, rain-filled, grassy ground depressions. According to Edwards (1941: 201), this species habitually feeds upon human blood.

DISTRIBUTION: *Specimens examined.* R.K.L. Luzon: Olongapo, Subic Bay, Zambales Prov. (Rozeboom, McMillan). Samar: Osmena (Laffoon, Rozeboom). Mindanao: Zamboanga, City of Zamboanga Prov. (Johnson, Knight, Laffoon). C. C. Luzon: Sison, Panagasinan Prov. (Franclemont). Baisas Coll. Luzon: Tunkong Manga, Bulacan Prov. U.S.N.M. Jinamoc Island (nr. Samar) (Medler). Mindanao: Males, females, Parang (Pallus). Pettit Barracks, Zamboanga (Visaya). Luzon: Males, females, Camp Nichols, Rizal Prov. (McDonald). Camp Stotsenberg, Pampanga Prov. S. Fernando, LaUnion Prov. (Shields.) Leyte: Males, females, Abuyog (Graham). One larva, Dulag (Starkey). C.A.S. Mindoro: San Jose (Ross).

Literature records. Luzon: Bayambang, Los Banos, Camp Nichols, Camp Stotsenberg (Bohart, 1945: 66). Mindoro: Calapan. Luzon: Manila (Edwards, 1929: 5).

Outside the Philippines this species is known from Africa, India, Ceylon, Andamans, Siam, Malaya, Sumatra, Java, Borneo, Celebes, Kabaena, Soemba, Timor, Amboina, and Queensland.

Subgenus AEDES Meigen s. str.

1818. *Aedes* Meigen, Syst. Beschr. 1: 13. Genotype: *cinereus* Meigen (Europe, North America).

ADULT: Dark brownish or reddish species with little or no ornamentation, tarsi all dark. Palpi short in both sexes. Vertex dorsum mostly broad-scaled. Scutellum narrow-scaled. Patches of broad white scales on propleuron, upper and posteromedian portions of sternopleuron, and on upper part of mesepimeron. Paratergite not scaled. Lower mesepimeral bristles absent but mesepimeron often with fine hairs posteriorly. Legs dark. Male with tarsal claws of fore leg unequal or equal, both toothed, midlegs with claws unequal or equal and with all combinations of being simple or toothed, hind legs equal and toothed or simple. Female tarsal claws equal, toothed, those on hind tarsi simple in some species. Tergite I with white scales along lateral border. *Terminalia:* Basistyle short, stout, no true basal lobe bearing various strikingly modified apical and subapical structures. Dististyle extremely various in form, sometimes bearing hairs but never with a true appendage present. Phallosome various but always divided into a pair of plates or rods. Claspettes absent. Various striking processes may be developed from the ninth or tenth segments. Female terminalia specifically modified.

LARVA: Similar to *Banksinella*. Antennal hair tuft single or branched (2–10). Head hair 4 with 2–7 branches; 5 single, or with 2–10; 6 single, or with 2–8. Comb with 8–14 scales arranged in regular or irregular row. Siphon with attached acus; distal pecten teeth usually more widely spaced. Anal plate incomplete; ventral brush with 10–15 tufts, all but basal 1–4 arising from a laterally connected barred area. Habitat a wide variety of fresh- and brackish-water ground pools, temporary or permanent.

DISTRIBUTION: Approximately 68 species are now recognized in the subgenus *Aedes*, of which the majority occur in the Australasian and Oriental regions. Thirteen species are known from the Philippines.

SYSTEMATICS: To date it has not been possible to divide the known species into any logical system of subgroups. For a detailed treatment of the known Philippine species, see Laffoon (1946).

Aedes (Aedes) robertsi Laffoon

1946. *Aedes* (*Aedes*) *robertsi* Laffoon, Jour. Wash. Acad. Sci. 36: 230 (males, females, larvae). Type locality: Philippines. Tacloban, Leyte (Roberts). Type: Male (holotype) in Academy of Natural Sciences of Philadelphia.

DISTRIBUTION: *Literature records.* Known only from type series.

Aedes (Aedes) hamistylus Laffoon

1946. *Aedes* (*Aedes*) *hamistylus* Laffoon, Jour. Wash. Acad. Sci. 36: 232 (males, females, pupae, larvae). Type locality: Philippines. Cape Melville, Balabac (Laffoon). Type: Male (holotype) in U.S.N.M.

DISTRIBUTION: *Literature records.* Known only from type series.

DISCUSSION: This species is apparently indistinguishable from *robertsi* except for the following characters. Male with claws of fore leg unequal, both toothed; claws of midleg unequal, the larger one simple, the smaller one toothed. Apical prolongation of basistyle more rounded than in *robertsi*, base of its inner posterior projection larger, with only a short blunt projection arising from it. Basistyle with two bristles close to outer base of prolongation, but with an area free of bristles for some distance anterior to these, a total of about 10 bristles on the basistyle. Female terminalia with the regions of densest sclerotization in the postatrial area differing. No means of separating the larva from that of *robertsi* has been found. The larvae of *robertsi* and of this species are unusual in that the

anal papillae are extremely long and possess prominent tracheation. This rather unusual structural detail is apparently correlated with their ability to remain nearly indefinitely at the bottom.

Aedes (Aedes) dux Dyar and Shannon

1925. *Aëdes* (*Aëdes*) *dux* Dyar and Shannon, Insecutor Inscitiae Menstruus 13: 81 (male). Type locality: Philippines. Type: Male (holotype) in U.S.N.M.

1928. *Aedes* (*Aedes*) *sigmoides* Barraud, Indian Jour. Med. Res. 16: 373 (female). Type locality: Andaman Islands. Port Blair (Christophers). Type: Female (holotype) in B. M.† Terminalia mounted.

1937. *Aedes* (*Aedes*) *dux* Dyar and Shannon. Causey, Amer. Jour. Hyg. 25: 414. Synonymy of *sigmoides*.

1945. *Aedes* (*Aedes*) *macrodixoa* Dyar and Shannon. Bohart, Synopsis of Philippine Mosq., NavMed 580, p. 65 and figure 52 (female only).

Adult and larva described by Laffoon (1946: 233).

DISTRIBUTION: *Specimens examined*. C.A.S, Mindoro: 2 females, 1 set assoc. skins, 1 larva. San Jose (Ross). C. C. Luzon: 19 females, Santo Tomas, LaUnion Prov. (Franclemont).

Literature records. Luzon: Camp Nichols and Las Pinas, Rizal Prov. Tungkong Manga, San Jose, Bulacan Prov. Manila, Manila Prov. Subic Bay, Zambales Prov. Camp Stotsenberg, Pampanga Prov. Mindoro: Caminawit Point. Mindanao: Zamboanga, City of Zamboanga Prov. (Laffoon, 1946: 235.)

Outside the Philippines this species is known from Java, Malaya, Siam, Andaman Islands, and Indo-China.

DISCUSSION: Laffoon (1946: 235) questioned the synonymy of *sigmoides* by Causey because Barraud's original description stated that the type had small, lateral, pale markings on the abdominal tergites. However, the senior author has had the opportunity of comparing Philippine specimens with the type of *sigmoides*, and there seems to be no doubt but that they are conspecific. Philippine specimens show paler brown areas basolaterally on some tergites, and in some specimens these areas even show a grayish color as does the type of *sigmoides*.

In general appearance *dux* most closely resembles *robertsi* and *hamistylus*. However, it may be readily distinguished from them because of the hind tarsal claws, which are simple in the former and toothed in the latter two.

Aedes (Aedes) johnsoni Laffoon

1946. *Aedes* (*Aedes*) *johnsoni* Laffoon, Jour. Wash. Acad. Sci. 36: 235 (males, females, pupae, larvae). Type locality: Philippines. Pasanonco, City of Zamboanga Prov., Mindanao (Johnson). Type: Male (holotype), with associated larval and pupal skins, in U.S.N.M.

DISTRIBUTION: *Literature records*. Known only from the type series. Leyte: Tanauan. Mindanao: Pasanonco, San Ramon, and Zamboanga Prov. Basilan: Isabela.

DISCUSSION: *Aedes johnsoni*, *margarsen*, *adustus*, and *andamanensis* (not recorded from the Philippines) make up a complex that is probably either polytypic or superspecific in form.

Aedes (Aedes) adustus Laffoon

1946. *Aedes* (*Aedes*) *adustus* Laffoon, Jour. Wash. Acad. Sci. 36: 236 (males, females). Type locality: Philippines. Cape Melville, Balabac Island (Howell). Type: Male (holotype) in U.S.N.M.

DISTRIBUTION: *Literature records*. Known only from the type series.

DISCUSSION: In the adult stage this species is very similar to *johnsoni* and *margarsen*, differing only in details of the male terminalia. The larva is undescribed.

A very unusual specimen was taken as a larva in the pool from which part of the type series of *adustus* was taken (Laffoon, 1946: 236). It is inseparable from the male of *adustus*

on external characters, but the terminalia are asymmetrical (Laffoon, 1946, fig. 14). One side is rather similar to *adustus*, while the other is very odd, showing some similarity to *campylostylus* and some to *adustus*. The larvae of *campylostylus*, *hamistylus*, and *uncus* were collected from this same pool. This specimen is in the U.S.N.M.

While at the British Museum in 1946, the senior author compared a Philippine male specimen of *adustus* with the holotype male of *andamanensis* Edwards and made a note to the effect that the two were conspecific. Word of this was sent to Laffoon, and, after reviewing the problem, he replied that he had used the figure given by Barraud (1934, fig. 71g) for his concept of the male terminalia of *andamanensis*. This figure shows three apical processes in addition to the tergal large one and is accordingly similar to *johnsoni* (differing, however, in the shape of the anterior fork elements of the dorsal large prolongation); and probably represents an undescribed species. No specimen that could have been used for this description was located in the collection of the B.M., so perhaps the specimen in question is still in the collection at Kasauli.

Barraud (1934: 290) recorded seeing specimens of *andamanensis* from the Andamans, Assam, E. Bengal, and the Malabar Coast. Four of Barraud's specimens from Assam are in the B.M., and an examination of the terminalia of a male in this series showed it to be unlike his figure and completely similar to the type of *andamanensis* in lacking the third of the three apical processes below the large tergal prolongation. Therefore, Barraud's figure must have been made from either E. Bengal or Malabar Coast specimens. However, the identity of his species must remain unknown until someone has the opportunity of re-examining his material that is still at Kasauli.

To return to the possibility of *adustus* being a synonym of *andamanensis*, Laffoon pointed out (in personal communication) that Edwards' (1922, fig. 37) original figure showed a series of short hairs along the tergal-lateral margin of the basistyle, whereas *adustus* possesses a group of about 10–15 long bristles tergal-laterally on the basistyle, and these are all arranged apically at the base of the tergal prolongation. No such group is shown in the figure given by Edwards. Other differences pointed out by Laffoon that might serve to separate the two species are the different shape of the anterior fork of the large apical prolongation of the basistyle and the different form of the group of stout spines on the inner basal surface of the basistyle. Unfortunately, Laffoon's letter did not arrive until after the departure of the senior author from the B.M., and these possible points of difference have not been checked. So, for the present, *adustus* has been maintained as a valid species.

Aedes (Aedes) margarsen Dyar and Shannon

1925. *Aëdes* (*Aëdes*) *margarsen* Dyar and Shannon, Insecutor Inscitiae Menstruus 13: 80 (males, females). Type locality: Philippines. Camp Eldridge, Laguna Prov., Luzon (Vasquez). Type: Male (lectotype) in U.S.N.M.

Adult and larva described by Laffoon (1946: 237).

DISTRIBUTION: *Literature records*. Luzon: Camp Eldridge, Los Banos, and Calamias, Laguna Prov. Tungkong Manga, San Jose, Bulacan Prov. Subic Bay, Zambales Prov. San Anastacio. Mindoro: San Jose. (Laffoon, 1946: 237.)

Unknown outside the Philippines.

DISCUSSION: The adult of this species is distinguishable from *andamanensis*, *johnsoni*, and *adustus* only in details of the male terminalia. The larva is apparently inseparable from the larva of *johnsoni*.

Aedes (Aedes) nubicolus Laffoon

1945. *Aedes* (*Aedes*) *uncus* (Theobald). Bohart, Syn. Philippine Mosq., NavMed 580, p. 66 and fig. 50. Male only.

1946. *Aedes* (*Aedes*) *nubicolus* Laffoon, Jour. Wash. Acad. Sci. 36: 237 (2 males). Type locality: Philippines, Sibulan River, at 7,000–8,000 feet on Mount Apo, Cotabato Prov., Mindanao (Clagg). Type: Male (holotype) in Museum of Comparative Zoology, Cambridge, Mass.

DISTRIBUTION: *Literature records.* Known only from the type series.

DISCUSSION: This species, which is known only from the male, is apparently indistinguishable externally from *macrodixoa* and *uncus*. However, the male terminalia is distinct from that of all species known.

Aedes (Aedes) uncus (Theobald)

1901. *Culex uncus* Theobald, Mon. Cul. 2: 53 (2 females). Type locality: Malaya. Klang, Selangor (Butler). Type: 2 females (cotypes) in B.M.† Terminalia mounted. These two specimens are not conspecific. Therefore, at this time the name *uncus* is restricted to the specimen bearing the following penciled label: "Klang. Among plantains." The other female, labeled "Klang jungle. IX.99" in ink on the back of the card supporting the pin, is an unnamed species.

1908. *Aioretomyia Varietas* Leicester, Cul. Malaya, p. 185 (1 male, 2 females in type series). Type locality: Malaya. Kuala Lumpur (Leicester). Type: 1 male, 2 females (cotypes) in B.M.† Both male and female terminalia mounted. The two females are conspecific with *uncus* (new synonymy). The male is a distinct species, and at this time the name *varietas* is restricted to this male specimen.

Adult described by Laffoon (1946: 237).

DISTRIBUTION: *Literature records.* Culion. Palawan: Puerto Princesa. Irahuan River Valley. Balabac Island: Cape Melville. (Laffoon, 1946: 238.)

Known outside the Philippines only from Malaya.

The Mt. Apo, Mindanao, record of Bohart (1945: 66) was based upon the type specimens of *nubicolus*.

DISCUSSION: The two specimens (Edwards, 1917: 223, stated that there was only a single type specimen) used by Theobald in describing this species have been examined by the senior author and found not to be conspecific. As pointed out in the synoptic table above, the specimen bearing the label "Klang. Among plantains." has been selected as the type for *uncus*. The other specimen apparently represents an undescribed species or at least one in which the female stage is unknown.

The specimen selected as type has a rather poor terminalic mount, but it was possible to see all of the structures except the preatrial sclerite and the preatrial plate. In all details seen, the terminalia compared well with a female terminalia of what has been considered to be *uncus* in the Philippines by Laffoon (1946: 237). However, externally this type specimen differs slightly, as follows: only 7–9 hairs on the anterior part of the sternopleuron, and about 20 fine hairs scattered all along the posterior margin of the sternopleuron. This difference in the number of hairs on the anterior portion of the sternopleuron is sufficient to keep this specimen from keying to *uncus* in the key to the Philippine species of the subgenus *Aedes* prepared by Laffoon (1946: 229).

The other female type specimen differs completely from *uncus* as treated here in lacking anterior sternopleural hairs altogether and in having only up to 4 hairs on the mesepimeron below the dorsal hair tuft (these occur posterior to the scale patch). The terminalia of this specimen resembles that of *campylostylus* except that there are apparently no postatrial hairs. However, the slide is very faded, and it was only possible to say that it was not *uncus* as figured by Laffoon (1946, fig. 21).

Edwards (1917: 223) arbitrarily associated two Malayan male specimens from Leicester's collection with Theobald's types of *uncus*. Ex-

ternally, these two specimens appear unquestionably to be conspecific with the specimen selected above as the type for *uncus*. They differ externally from Philippine *uncus* in the same manner described above for the female. Also, the terminalia, as figured by Edwards (1917, fig. 8d) shows some minor differences. Unfortunately, no notes were made of these differences so it is not possible to evaluate them now.

In summary, it seems likely that the Philippine material may eventually be shown to be either subspecific to *uncus*, or a separate, closely related species. On the other hand, more extensive collecting in Malaya and the adjoining portions of the Philippines may show the variations mentioned to be normal and intraspecific. This is the only fresh-water species of the Philippines with a distribution elsewhere, and it seems likely that this may be additional evidence to show that the Philippine form is a distinct and endemic form.

In examining the types of *varietas* Leicester, it was noted that externally the two female cotypes are similar to the female selected as type for *uncus*, in both general and specific characters. In these, the number of hairs on the anterior portion of the sternopleuron was slightly higher (and thus more intermediate with the Philippine material), being 10–12 in number. Although the terminalic mount available was not too good, it appeared to resemble completely that of the female type of *uncus*.

The male cotype of *varietas* is not conspecific with the females and is here regarded as the type for that species. It is a smaller species than *uncus* and has a general grayish-brown appearance, very small basolateral spots on the tergites, and delicate, thin hind tarsal claws.

Aedes (Aedes) macrodixoa
Dyar and Shannon

1925. *Aëdes* (*Aëdes*) *macrodixoa* Dyar and Shannon, Insecutor Inscitiae Menstruus 13: 79 (1 male). Type locality: Philippines. Infanta, Tayabas Prov., Luzon. Type: Male (holotype) in U.S.N.M. Terminalia mounted.

Adult and systematics treated by Laffoon (1946: 238).

DISTRIBUTION: *Literature records*. Luzon: Infanta, Tayabas Prov. Mindoro: San Jose. Leyte: Tacloban. Mindanao: Mercedes, City of Zamboanga Prov. Parang. (Laffoon, 1946: 239.)

Unknown outside the Philippines.

DISCUSSION: This species is apparently indistinguishable externally from *uncus* and *nubicolus*. Laffoon (1946: 239) has pointed out that the female which Bohart (1945, fig. 52) identified and figured as *macrodixoa* is in actuality *dux*.

According to King and Hoogstraal (1947: 125), the male from the upper Digoel River in southern Dutch New Guinea that was identified by Brug (1932: 79) as *macrodixoa* was probably *neomacrodixoa* King and Hoogstraal.

Aedes (Aedes) nigrotarsis (Ludlow)

1908. *Pseudoskusea nigrotarsis* Ludlow, Canad. Ent. 40: 52 (female). Type locality: Philippines. Infanta, Tayabas Prov., Luzon (Warriner). Type: Female (holotype) in U.S.N.M.

1908. *Pseudoskusea mediolineata* Ludlow. Canad. Ent. 40: 332. Misidentification.

Adult, larva, and systematics treated by Laffoon (1946: 239).

DISTRIBUTION: *Literature records*. Luzon: Infanta. Subic Bay, Zambales Prov.; Camp Nichols, Rizal Prov.; Calauan, Laguna Prov.; Quezon City, Manila Prov.; Wackwack; Manila, Manila Prov. Samar: Osmena. Jinamoc Island. Leyte: Tacloban. Abuyog. Mindanao: Zamboanga and San Ramon, City of Zamboanga Prov. (Laffoon, 1946: 240.) Leyte: Tolosa (Bick, 1949: 4).

Unknown outside the Philippines.

DISCUSSION: This species is closely related to *indicus* (Theobald), which is known only

from India. Of the Philippine fauna, *campylostylus* most nearly resembles *nigrotarsis*.

Aedes (Aedes) campylostylus Laffoon

1946. *Aedes* (*Aedes*) *campylostylus* Laffoon, Jour. Wash. Acad. Sci. 36: 240 (males, females, pupae, larvae). Type locality: Philippines. Balsahan River, Palawan (nr. Iwahig) (Fitzjarrell). Type: Male (holotype), with associated larval and pupal skins, in U.S.N.M.

DISTRIBUTION: *Literature records*. Known only from the type series. Leyte: Tacloban. Mindoro: San Jose. Palawan: Balsahan and Irahuan River Valleys. Balabac: Cape Melville. Mindanao: San Ramon, City of Zamboanga Prov. (Laffoon, 1946: 242.)

Aedes (Aedes) panayensis Ludlow

1914. *Aëdes panayensis* Ludlow, Psyche 21: 159 (49 males and females). Type locality: Philippines. Iloilo, Panay (Ewing). Type: Male (lectotype) in U.S. N.M.

1929. *Aëdes* (*Aëdes*) *panaygensis* Ludl. Edwards, Notulae Ent. 9: 3. Lapsus.

Adult and systematics treated by Laffoon (1946: 242) and adult by King and Hoogstraal (1947: 119).

DISTRIBUTION: *Literature records*. Panay: Iloilo. Calicoan Island (nr. Guiuan, Samar). Culion Island. Balabac. Mindanao: Zamboanga, City of Zamboanga Prov. (Laffoon, 1946: 243.)

Outside the Philippines, known from Morotai, Schouten Islands, and Ceram.

DISCUSSION: The male of this species is especially distinctive in having the fore and mid-tarsal claws equal and toothed. On the basis of male terminalia, the closest relatives to *panayensis* appear to be the Sumatran species *dermajoensis* Brug and *prioekanensis* Brug.

The larva is undescribed.

Aedes (Aedes) butleri Theobald

1901. *Aedes Butleri* Theobald, Mon. Cul. 2: 230 (3 females). Type locality: Malaya. Selangor (Butler). Type: 3 females (cotypes) in B.M.† The specimen which does not have the terminalia mounted is probably a *Skusea* species. The other two specimens, both of which have the terminalia mounted, are conspecific and are here selected as representing *butleri*.

1903. *Skusea diurna* Theobald, Entomologist 36: 259 (female). Type locality: Malaya. Jugra, nr. Kuala Lumpur (Durham). Type: Female (holotype) in B.M.† Terminalia mounted.

1903. *Verralina Butleri*. Theobald. Theobald, Mon. Cul. 3: 295. Different combination.

1910. *Stegomyia hatiensis* Carter, Entomologist 43: 275 (5 females). Type locality: Cochin China. Ha-tien (Broquet). Type: 2 females (? lectotypes) in B.M.† Terminalia mounted.

1924. *Aëdes* (*Skusea*) *umbrosus* Brug, Bul. Ent. Res. 14: 437 (4 males, 2 females). Type locality: Borneo. Tanah Grogot, S. E. Borneo (Brug). Type: 2 males, 1 female (cotypes) in B.M.† Terminalia mounted for 1 male and 1 female.

1928. *Aëdes* (*Aëdes*) *umbrosus*, Brug. Edwards and Given, Bul. Ent. Res. 18: 345. Description of larva.

1946. *Aedes* (*Aedes*) *umbrosus* Brug. Laffoon, Jour. Wash. Acad. Sci. 36: 243. Tentative synonymy to *butleri*.

Barraud (1934: 296), female only, male is probably *lugubris* Barraud. Laffoon (1946: 243), adult, larva, and systematics.

DISTRIBUTION: *Literature records*. Leyte. Tacloban and Palo. Culion Island. Palawan: Iwahig and Puerto Princesa. (Laffoon, 1946: 244.)

Outside the Philippines known from Borneo, Java, Malaya, Cochin China, India, and the Andamans.

DISCUSSION: The types of *butleri* have been examined, and a female terminalic slide of a Palawan specimen was compared with them. There appears to be no essential differences.

As pointed out in the synonymic table, the female without terminalia separated is an undetermined species. It possesses broad scales on the scutellum and on *ppn* and lacks fine hairs on the mesepimeron. It is probably a *Skusea* species, but this point was not checked.

Two female terminalia labeled as this species by Barraud in the British Museum collection from the Andamans (ix. 1911. Christophers) were examined and seemed to check satisfactorily with the types.

The types of *diurna* and *hatiensis* were examined and found to be *butleri*, as previously indicated by Edwards and Barraud. Laffoon (1946: 245) had questioned the synonymy of *hatiensis* because Carter in his description said that the scutellar scales were similar to those covering the greater portion of the head, thus implying that they were broad. However, in examining the two Ha-tien specimens pinned under *butleri* in the British Museum, it was found that both are pinned through the scutellum, making it now impossible to know what type of scales were present. It seems likely that the missing three specimens (two from Ha-tien and one from Saigon) had broad scutellar scales and were moved by a later worker (probably Edwards) to an *Aedes* species with broad scutellar scales.

The types of *umbrosus* were studied, and the female terminalia was compared with that of a specimen from Palawan. No essential differences were found. No Philippine male specimen was available for direct comparison, but the type male terminalia was compared to the figure given by Laffoon (1946, fig. 1) and found to agree perfectly, except that the type specimen (only one had the terminalia mounted) had three proximated subapical spines instead of only two as figured by Laffoon, had only 13–15 verticillate bristles on the antennal segments, and was somewhat smaller. No differences were found between the female type of *umbrosus* and the types of *butleri*, *diurna*, and *hatiensis*. The Javan specimen mentioned in the original description of *umbrosus* was not seen in the British Museum.

As pointed out by Laffoon (1946: 245), the male terminalia described and figured by Edwards (in Barraud, 1934, fig. 73e, f) as the male of *butleri* is probably the male of *lugubris*. No Indian specimens of *butleri* were seen in the British Museum.

Subgenus CANCRAËDES Edwards

1929. *Cancraëdes* Edwards, Bul. Ent. Res. 20: 342. Genotype: *cancricomes* Edwards (Andaman Islands).

ADULT: Brownish species without special ornamentation. Palpi very short in both sexes. Vertex and scutellum all broad-scaled. Stout dorsocentral bristles present, but no acrostichals. Paratergite not scaled. Lower mesepimeral bristles present. Tarsal claws simple in both sexes. *Terminalia:* Basistyle short, with a complex group of apical and subapical appendages. Dististyle very short, simple, without articulated appendage. Claspettes absent. Mesosome divided, each lobe with an elongate spine externally.

LARVA: The larva of only one species has been described. As in subgenus *Aedes* except: Comb with about 70 scales arranged in a patch. Ventral brush with about 8 tufts, all borne on a laterally connected barred area. Habitat, crab holes and pools in mangrove swamps.

DISTRIBUTION: The four known species (a fifth species, *kanarensis* Edwards, 1934, was questioningly placed in this subgenus by the describer) are confined to the Oriental region.

SYSTEMATICS: Except for *kanarensis*, this subgenus contains a very uniform group of species. *A. kanarensis*, which has not been included in the above subgeneric description, differs markedly from the other known species in the subgenus because of its scutal and tarsal pale scaling.

Aedes (Cancraëdes) miachaetessus
Dyar and Shannon

Fig. 12

1925. *Aëdes* (*Skusea*) *miachaetessa* Dyar and

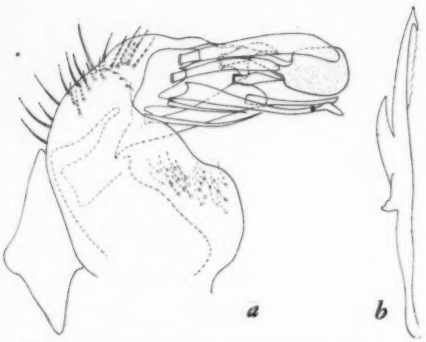

FIG. 12. *A.* (*Cancraëdes*) *miachaetessus*. Male terminalia (Samar). *a*, Lateral aspect of basistyle, lateral surface of basistyle omitted; *b*, left half of mesosome.

Shannon, Insecutor Inscitiae Menstruus 13: 78 (2 females). Type locality: Philippines. Camp Stotsenberg, Pampanga Prov. Luzon (Tefft). Type: 2 females (cotypes) in U.S.N.M.† One of these specimens is here designated lectotype.

1929. *A.* (*?Cancraëdes*) *miachaetessa*, Dyar and Shannon. Edwards, Bul. Ent. Res. 20: 342. Different combination.

ADULT: A very small dark species, without special markings.

Male. Wing length about 2.1 mm. *Head:* Proboscis dark. Palpus very short, no longer than the clypeus, dark. Torus bare. Vertex with broad dark scales, a few dark upright-forked scales on nape. *Thorax:* Scutal integument dark brown; with narrow dark scaling. Scutellar lobes with broad dark scales. *Apn* and *ppn* with a few narrow-curved dark scales. Pleuron yellowish brown in color, bare of scales except for a few translucent dusky broad scales dorsally on sternopleuron; a few short pale hairs dorsoanteriorly and ventroposteriorly on sternopleuron; 1–2 stout lower mesepimeral bristles. *Legs:* All dark. Tarsal claws simple, those of fore and midlegs unequal. *Wings:* Dark-scaled. Halter knob dark-scaled. *Abdomen:* Tergites and sternites dark-scaled. Segments V–VIII noticeably enlarged, VII–VIII much retracted, sternite VIII with apical half densely covered with very long hairs. *Terminalia:* As in figures. The one figure is a lateral view of the left basistyle. The basistyle in this species is extremely bulbous, and in order to show the dististyle and its subapical appendages adequately the outer surface of the basistyle is omitted from the drawing.

Female. Similar to the male except that the tergites have white basolateral patches, and the sternites are white basally. Tarsal claws equal, simple.

LARVA: Unknown.

BIONOMICS: Two males were collected from the mouths of crab holes.

DISTRIBUTION: *Specimens examined*. R.K.L. Samar: 1 male, Osmena (Laffoon, Knight). Mindanao: 1 male, Zamboanga (Knight, Laffoon). U.S.N.M. Luzon: 2 female types, Camp Stotsenberg, Pampanga Prov.

Not known from outside the Philippines. The two females from Koh Kut Island, Gulf of Siam, listed by Dyar and Shannon (1925: 78) have been examined (in U.S.N.M.) and are believed to be *curtipes* on the basis of the dark pleurae.

DISCUSSION: The male of this species had not previously been described. Of course, it is quite possible that the association of sexes made here is incorrect as the correlation is made solely on general appearance.

Aedes (Cancraëdes) curtipes Edwards

Fig. 13

1915. *Aëdes ?curtipes* Edwards, Bul. Ent. Res. 5: 283 (4 females). Type locality: Borneo. Kuching (?), Sarawak (Moulton). Type: Female (holotype) in B.M.†

1928. *Aëdes* (*Skusea*) *curtipes*, Edw. Edwards, Bul. Ent. Res. 18: 274. Different combination.

1929. *A.* (*Cancraëdes*) *curtipes*, Edw. Edwards, Bul. Ent. Res. 20: 342. Different combination.

Male described by Edwards (1928: 274). Larva described by Edwards and Given (1928: 346).

ADULT: *Male*. Wing length about 2.0 mm. Very similar to *miachaetessus* but differing slightly as follows: Pleural integument grayish brown to brown in color. *Ppn* with several fine short hairs ventroposteriorly. Mesepimeron with several fine pale hairs between the dorsal hair tuft and the lower mesepimeral bristles. Hind femur with basal half partially pale-scaled anteriorly. *Terminalia:* Resembling that of *miachaetessus* but the subapical appendages differing as figured. The basal portion of the basistyle of the single available specimen was somewhat broken so that details in that portion may not be accurately illustrated.

Female. As in male except that there are laterobasal pale patches on most of the tergites and basal paler scales on the sternites. Torus with some dark scales and hairs medially.

LARVA (from Edwards and Given, 1928: 346. No larvae taken in P.I.): *Head:* Antenna almost as long as head, with numerous spicules; antennal hair tuft with 5–6 branches, inserted just before middle and reaching the tip of the antenna. Preclypeal spines long, bristle-like. Head hair 4 with about 6 branches, very small; 5 with 3; 6 with 2; 7 with 7–10; 8 single; 5, 6, and 7 all large and plumose, and arranged in a slightly curved line. Mentum with about 15 lateral teeth. *Thorax:* Lateral tufts large and plumose; associated spines very short. *Abdomen:* Lateral tufts double, plumose on I and II. Comb with about 70 scales, each long, narrow, sharp, and simple. Siphon rather strongly tapering on the outer half, index about 2.7; acus distinct, narrow; 6–8 pecten teeth, mostly rather widely spaced and extending a little beyond middle of siphon, each tooth with 2–3 very strong denticles; siphon hair tuft with 3–5 branches, inserted beyond distal pecten tooth. Anal plate small; ventral brush of about 8 tufts, each tuft with a rather long stalk, no tufts off the barred area. Anal gills short, somewhat pear-shaped, dorsal pair almost as long as anal plate, ventral pair shorter.

BIONOMICS: Adults were collected flying at the edge of a mangrove swamp and from resting places inside the openings of crab holes. The larvae were not taken. However, Edwards and Given (1928: 346) reported the larvae from mangrove pot-holes.

FIG. 13. *A.* (*Cancraëdes*) *curtipes*. Male terminalia (Palawan). *a*, Mesal aspect of basistyle; *b*, left half of mesosome.

DISTRIBUTION: *Specimens examined*. R.K.L. Palawan: 1 male, 5 females, Iwahig Penal Colony (Laffoon). U.S.N.M. Palawan: 2 females, Puerto Princesa (19th M.G.L.).

Not previously reported from the Philippines.

Outside the Philippines this species is known from Borneo and Malaya. As pointed out in the treatment of *miachaetessus*, it is believed that the two female specimens in the U.S.N.M. from Koh Kut Island, Gulf of Siam, are this species.

DISCUSSION: The type was studied, but unfortunately a male terminalia was not seen. However, the male terminalia of the Palawan specimen agrees with Edwards' (1928, fig. 1) figure of the male terminalia of *curtipes*, except that he does not show the subapical append-

age A that is present in the Palawan specimen (see figure).

AEDES OF UNKNOWN SUBGENERA

Aedes (?) platylepidus Knight and Hull

1951. Aedes (?) *platylepidus* Knight and Hull, Pacific Sci. 5: 201 (3 females). Type locality: Philippines. Puerto Princesa, Palawan (Laffoon and Johnson). Type: Female (holotype)in U.S.N.M.†

DISTRIBUTION: *Specimens examined.* Known only from type series. Palawan: Puerto Princesa. Balabac: Cape Melville.

DISCUSSION: The male is unknown and the larva is not described. The type series was obtained from a larval collection but unfortunately no associated larval material was retained.

This species is strikingly different, on the basis of the broad plate-like dark (with metallic reflections) scutal and scutellar scales, from all other known Pacific *Aedes* species. Lack of the male and larva, together with the rather aberrant characters of the female, prevent the making of a definite decision at this time as to the subgeneric position in *Aedes* of *platylepidus*. The possible relationships of this species are discussed in some detail in the original description.

Aedes, species unknown

Three larval specimens from Palawan and Balabac represent an unknown aedine species. It is quite possible that this is either the larva of *Aedes platylepidus* or of *Heizmannia scintillans* Ludlow, but in the absence of associated material it is impossible to say definitely at this time.

LARVA: *Head:* Antenna smooth, rather stocky; antennal hair single, inserted near apex. Mouth brush with comb-like tips. Hair 4 single, rather long, dark, curved inward; 5 single; 6 with 2–3 branches; 7 single or double, small; 8 single; 9 double; 12 with 2–3; 13 and 14 single; 15 with 1–3; 17 and 18 single; 20 double; 18 is inserted just mesad and ventral to 17, rather than near the lower corner of the mentum. Mentum with 8–9 lateral teeth. *Thorax:* Prothoracic hairs 1 and 2 single; 3 with 3 branches. Mesothoracic hair 9 single; thoracic hairs in general quite sparsely branched. *Abdomen:* Dorsolateral hair on I with 2–3 branches; on II double. Lateral hair on I double; on II single or double; on III and IV with 3–4; on V and VI with 5–6. Pentad hair 1 with 2–3; 2 and 4 single; 3 with 2–6; 5 with 2–3. Comb with 6 teeth in a curved row, each tooth long, slender, sharply pointed, with a small amount of fringe laterally at the base of the spine. Siphon smooth, with an attached acus, index 2.1–2.4; 7–12 pecten teeth in an irregular row, each with fine fringe basally on ventral side and occasionally on dorsal side also; siphon hair tuft with 4–6 branches, inserted either before, near, or beyond the last pecten tooth. Anal plate apparently complete, with a few small spicules laterally on the posterior margin; *lh* with 3–4 short, rather stout branches; *isc* single (once double), *osc* single; ventral brush of 10 hairs, each single except for basal pair with 3–5 branches; no barred area present. Anal gills finger-like, dorsal pair slightly shorter than ventral pair and 2.2–2.5 times longer than anal plate.

BIONOMICS: This larva was taken on one occasion from water collected in a large metal packing container in the jungle and on another from water collected in a large, thorny palm frond lying on the ground at the edge of a mangrove area.

DISTRIBUTION: *Specimens examined.* R.K.L. Palawan: 2 larvae (#854) Irahuan River, 3 miles inland (Laffoon). Balabac: 1 larva (#1611), Cape Melville (Johnson).

One of the Palawan larvae is deposited in the U. S. National Museum as *Aedes* sp. #46. The other two are retained in the Knight collection.

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The Response of a Tropical Fish to Direct Current and Its Application to the Problems of Electrofishing in Sea Water[1]

MORRIS E. MORGAN[2]

METHODS OF ELECTROFISHING have been developed successfully for use in fresh-water ponds and streams, but this equipment is not effective in sea water because the high conductivity of salt water greatly changes the power requirements (Smolian, 1944). If this obstacle can be overcome, it is reasonable to assume that electrofishing can be conducted in the sea with a success which would be at least equivalent to that experienced in fresh water.

Electrofishing in fresh water is now widely practiced in Germany, the United States, and Canada, where it is used mainly as a new tool to supplement the facilities for study of fish populations. The progress made in Germany has been described by Smolian (1944) in a comprehensive report which includes a description of the equipment and techniques used in that country. In the United States, the first efforts concerned with the reaction of fish to electrical stimulation centered around the development of electric fish screens and began as early as 1917 (Holmes, 1948). However, a method of actually collecting fish in fresh-water streams was first developed in 1939 (Haskell, 1940).

Equipment used for electrofishing in fresh water has consisted mainly of small, portable, gas-driven generators which produced alternating current. However, Smolian (1944) reported that the greatest effect seemed to be realized from using direct current interrupted at frequent intervals. Large fish were affected more strongly than small ones. There was also considerable variation in the sensitivity of various species to electrical stimulation.

In reports from both the United States and other countries it has been emphasized that paralyzing, narcotizing, and attracting the fish can be accomplished only in the immediate vicinity of the electrodes. Outside this area the current merely irritates the fish and frightens them away.

While some reports have been made concerning the injurious or fatal effects of electrofishing (Hauck, 1949), it appears that fish can be collected by using current strengths below those which will injure or kill.

German scientists have been investigating the possibility of adapting electrofishing techniques for use in salt-water fisheries. At the present time it has been reported (Anon., 1951) that they are in the process of installing electrical fishing gear on a boat of the type used in the trawl fishery. Only general newspaper-type reports have been published concerning this work. The basic research was financed personally by the scientists concerned so it is assumed that no detailed information will be forthcoming until their work has reached a patentable stage.

These reports indicate that their claims of success in the development of electrofishing equipment suitable for use in sea water are based on the more efficient utilization of electricity rather than in merely increasing the amount. Special mention is made of pulse shape, pulse rate, and electrode arrangement.

The response of living organisms to electrical stimulation was investigated as early as

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1885 by Hermann. He reported that tadpoles, when in a field of direct current of proper strength, would react by orienting themselves with their heads toward the positive pole. Since that time, experiments have been conducted with numerous animals, including crabs, fish, and frogs. Practically all types of animals tested show an orientation to the current. Many protozoans, however, orient and migrate toward the negative pole rather than the positive (Heilbrunn, 1948: 597).

Considerable research has been done in an attempt to explain the physiological reasons for this reaction (Breuer, 1905; Scheminsky, 1924; Van Harreveld, 1937). However, these reports indicate that it is still imperfectly understood. As nearly as can be determined, no satisfactory explanation of this phenomenon has been given.

I wish to express my appreciation for the advice and assistance given by Dr. A. L. Tester in the preparation of this manuscript and over-all supervision of the investigation.

METHODS

The period covered by the investigation here reported extended from May, 1950, to March, 1951. Work was begun at the Hawaii Marine Laboratory on Coconut Island and continued there throughout the summer months. At the beginning of the academic year, all the equipment was transferred to the Waikiki branch of the Hawaii Marine Laboratory. This branch, operated in conjunction with the Honolulu Aquarium, offered certain advantages over the previous site, principally its proximity to the University of Hawaii. All the detailed experimental work reported in the following pages took place at the latter site.

Power Supply

The generating equipment was selected to give the widest possible range in current and voltage while still being portable and of standard design.

As direct current was more likely to produce the reaction desired, an Onan two-cylinder, gas-driven, air-cooled, portable-type, direct-current, motor-generator set was purchased. It was rated at 5,000 watts (21.8 amperes at 230 volts). Special equipment included a voltmeter, ammeter, rheostat, and circuit breaker.

Electrodes

The high conductivity of the sea water caused serious overloading of the generator. Plans for overcoming this difficulty centered around the use of rheostats and suitable electrodes. However, the rheostat installed to control the voltage and current was ineffective and various other resistors devised to control the current flow proved unsatisfactory. A special electrode was finally developed for use during the experiments. This consisted of a carbon rod 6 inches long and ¼ inch in diameter inserted into a plastic tube (Fig. 1). The size and number of holes in this tube governed the flow of current. In effect the column of sea water inside the tube became the electrode, as the area of this column in

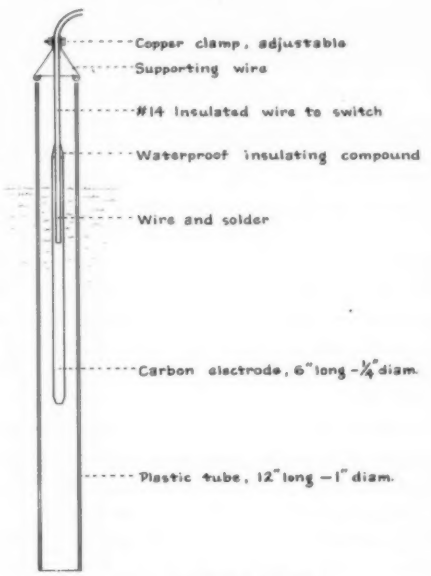
Copper clamp, adjustable
Supporting wire
#14 insulated wire to switch
Waterproof insulating compound
Wire and solder
Carbon electrode, 6" long - ¼" diam.
Plastic tube, 12" long — 1" diam.

FIG. 1. Electrode design.

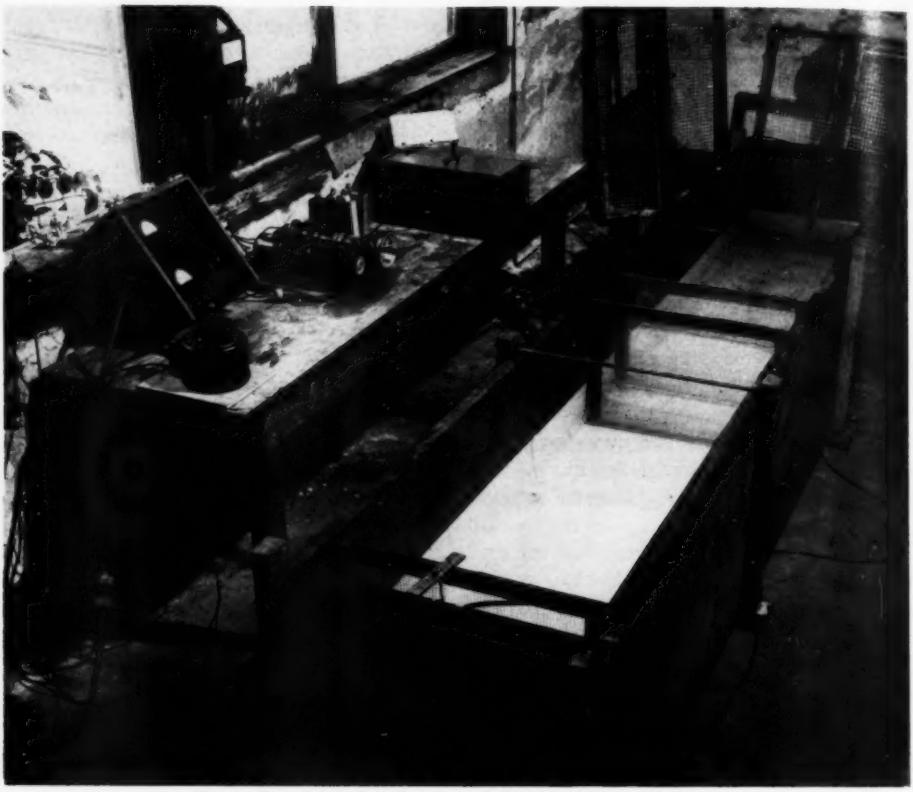

FIG. 2. Experimental tank and current-interrupting equipment.

contact with the main body of water in the tank determined how much current would flow. As the entire electrode was covered by water, gases formed on its surface evenly, and their escape did not affect the current flow. With this arrangement, it was possible to lower the enclosed electrode to any depth without changing the current flow, and a more symmetrical field could be created at each end of the tank.

Carbon was chosen as the most suitable electrode material because it is a fair conductor, inexpensive, and does not erode rapidly with electrolysis as do most metals.

To remove the products of electrolysis as they were formed and to prevent contamination of the water (chiefly by chlorine) in the tank, the water within each electrode was siphoned off continuously be means of a rubber tube. The loss of water from the tank was compensated for by a steady addition of new water.

Tank

A tank measuring 2 × 2 × 12 feet was constructed from redwood. The inner surface was thoroughly impregnated with heated paraffin to prevent leaching and to aid in waterproofing. Net barriers were placed about 1 inch in front of each electrode to prevent the fish from injuring themselves by contact with the electrode. Two other net barriers were arranged across the center of the tank to form a small area in which the fish could be held

when not actually under observation (Fig. 2).

Current Interrupter

After overloading had been controlled, preliminary experiments showed that the full load of the generator, approximately 20 amperes and 230 volts, would not attract and hold fish about 4 inches long in a concrete tank 10 feet square filled with water to a depth of 2 feet. When the fish swam near the electrodes, they were effectively held, but they would remain at the greatest distance possible from the electrodes or in the corners of the tank near the bottom.

Thus it became obvious that, if a steadily flowing current was to be used, a much greater source of power would be needed. A similar observation was made by Peglow (1949). To attract the fish to the positive pole a much more efficient use of the available power would be necessary. The best possibility of accomplishing this, according to the general reports of previous investigators, would be through the use of interrupted current (Smolian, 1944; Anon., 1950).

Various mechanical devices were constructed, mainly from war surplus material, for the interruption of direct current. First attempts centered around the use of relays, but for various reasons these did not prove practicable. It was difficult to determine the exact duration of the power-on period compared with the power-off period. When operating at higher interruption frequencies and with the higher power values, the arc became very difficult to control, even with condensers. Observation of the wave form on an oscilloscope showed that, if the power-off period was short, the arc often lasted over the entire period. The relay points frequently became heated and failed to separate. It was also difficult to determine the exact number of interruptions per second.

A revolving disc-type interrupter was finally decided upon. Although not satisfactory in every respect, it at least overcame most of the objectionable features of previous equipment (Fig. 3).

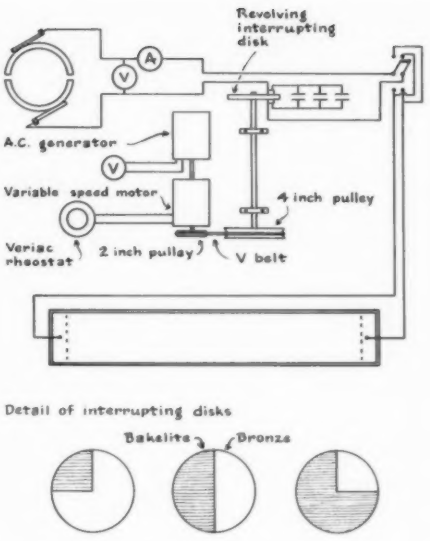

FIG. 3. Diagram of current-interrupting equipment used in experiments.

Carbon brushes bearing on either side of the disc provided a constant connection when the bronze portion of the disc was between them. When the disc revolved, the connection was definitely broken when the Bakelite portion was between the brushes. Some arc was unavoidable, but an attempt was made to minimize this by three condensers (10 mfd., 600 volts, d.c.) arranged in parallel. A variable speed motor controlled by a "veriac" was used to turn the disc.

A small generator was connected directly to the shaft of the motor. The voltage produced by the generator was recorded on a voltmeter. The relationship between voltage and speed was determined so that, by reading the voltage on the voltmeter, the speed of the generator and, therefore, of the motor could be calculated.

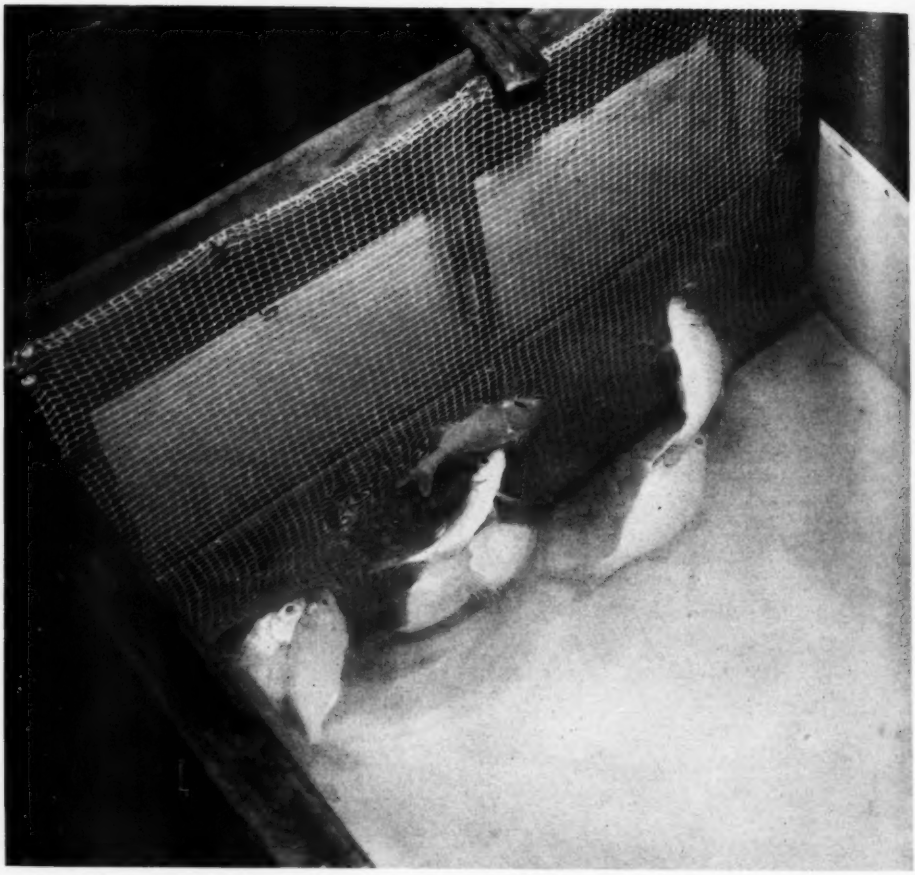

FIG. 4. The experimental fish, *Kuhlia sandvicensis* (Steindachner), attracted to the positive pole and immobilized there by the use of interrupted direct current.

Fish

The fish chosen for the experiments was *Kuhlia sandvicensis* (Steindachner) (Fig. 4), locally called aholehole. This fish is bright silvery when viewed from the side but appears dark blue when seen from above. It spawns along the shoreline and is quite plentiful in the brackish water near the mouths of streams and canals where it grows to a size of approximately 25 cm.

Aholehole were recommended for the experiments because of their hardiness and ability to survive considerable handling. This turned out to be a fortunate choice, for enough of the fish were caught in traps in Ala Wai Canal to supply all experimental needs. The fish were held and fed in tanks of the Honolulu Aquarium when not actually being used for experimentation. They proved to be admirably suited for the purpose intended. After a rather high initial mortality due to injury by trapping, practically none died, either from handling or from the effects of electrical shocks.

Experimenters have been unanimous in their reports that larger fish are affected more

strongly than smaller fish, so an attempt was made to control this factor by selecting fish of approximately the same size for the experiments. The range in size was from 9.5 cm. to 15.0 cm., the mean size was 11.8 cm., and the standard deviation was 1.04 cm.

Procedure

The collection of quantitative data on the reaction of fish to electrical stimuli was considered highly desirable, and an experimental plan was formulated with this in mind. The main object of the experimental work was to cause the fish to move, involuntarily, to the positive pole, where it would be held, either by a strong attractive force or by passing into a condition of electronarcosis. To eliminate, as far as possible, subjective observations and to measure this effect under different electrical conditions, the experimental design discussed in the following paragraphs was used.

The tank was considered to consist of two equal sections, positive and negative. The fish were held in the center of the tank between two net barriers. When the power was turned on, the barriers were removed. The power remained on for 60 seconds. During this period, the time the fish spent in the positive section was recorded. Under optimum electrical influence, the fish, when released from the center area, would move directly to the positive pole and become immobilized, thus spending the full period of 60 seconds in the positive section. When no influence was in effect, the fish (over an average) would be expected to spend 30 seconds in the negative section and 30 seconds in the positive section.

A two-pole, double-throw switch was placed in the circuit so the polarity could be reversed. This obviated the possibility that some influence other than electrical stimulation might cause the fish to seek one end of the tank more consistently. Each fish was given two timed trials, the polarity being reversed in the second trial. To determine whether the movements of the fish in the tank were random, preliminary trials were made with the power off. Ten tests were made using individual fish. They spent an average of 31.8 seconds in the positive section and 28.2 seconds in the negative section. These average times did not deviate significantly from the expected times of 30 seconds in each end of the tank, so it was concluded that movement throughout the tank was random when the current was off. Timed trials were also made with several fish in the tank at the same time. However, individual variation made accurate timing of each fish difficult, so it was decided that fish would be used individually rather than in groups.

During the experiments, the voltage remained relatively constant (220–230 volts). The depth of water in the tank was 12 inches, and the distance between electrodes was 11 feet. These factors were constant for all tests.

One group of experiments was conducted with continuously flowing (uninterrupted) current. In it were included a series of experiments at amperages of 1 to 14, inclusive. The current in amperes may be converted to density in milliamperes per square inch by multiplying the amperage by the factor 3.62. Thus, 14 amperes is equivalent to a current density of 51 milliamperes per square inch.

Three other groups of experiments were conducted with interrupted current using different periods of impulse duration (pulse time). The variation in impulse duration was obtained by using rotating discs with different bronze-Bakelite combinations as already described. In the first group, the disc used was half bronze and half Bakelite. Thus, during each revolution the power was on for one half the time and off for one half the time (1:1 on-off ratio). In the second group of experiments, the disc was three-fourths bronze and one-fourth Bakelite. During each revolution the power would then be on three times as long as it would be off (3:1 on-off ratio). In the third group of experiments one fourth of the interrupting disc was bronze while three fourths was Bakelite. In this case the power was on one fourth of the time and off three

fourths of the time during each revolution (1:3 on-off ratio).

Each group of experiments with interrupted current included several series at successively greater amperages. In group I, amperages of 1, 2, 3, 4, and 5 were used. In group II, amperages of 4, 5, 6, 7, and 8 were used. In group III, amperages of 2, 3, and 4 were used. At each amperage within a group, experiments were conducted at several frequencies of interruption. Frequencies used in group I were 5, 10, 15, 20, and 25 interruptions per second. In groups II and III, frequencies of 5, 15, and 25 interruptions per second were used. In each individual experiment, five fish were used and two trials were made with each. The polarity was changed with each trial. In all groups of experiments, successive tests were conducted until a current value was reached that would cause all fish to move to the positive pole and remain there for the full 60 seconds of each time period. If the frequency of current interruption proved to be a factor in causing the desired effect, this would be shown by variation in the times recorded for the different interruptions when both current and voltage remained constant.

RESULTS

Continuous Direct Current

The results of tests using uninterrupted (continuously flowing) current are shown in Table 1. The fish showed no effects of the current flow at 1, 2, and 3 amperes. At a current value of 4 amperes, the fish swimming near the electrodes, within about 6 inches, would suddenly veer away as though shocked. This effect became noticeable at greater distances from the electrode as the current was increased. At 7 amperes some fish were more strongly shocked in the immediate vicinity of the poles, but reactions were entirely evasive. The fish would swim toward one end of the tank; upon nearing the pole and receiving a shock they would turn and swim rapidly toward the opposite end, where the experience would be repeated.

At a current value of 9 amperes the fish entering the area near the positive pole would show the typical electronarcotic effect, including cramped, slow movements and slowing of opercular action, which resulted in respiratory difficulties. If the fish were at right angles to the lines of force between the electrodes, the body would be bent with the head and tail pointing toward the positive electrode. However, the electrical field was still not powerful enough to hold the fish and they were able to escape this influence, avoid the vicinity of the pole, and swim to an area in the tank where they were affected least.

At current values above 10 amperes practically all fish started swimming toward the positive pole when the center barriers were removed but were repulsed rather than held by the increasing effects as they neared the positive pole. The result was that they remained either in a low-current density area at the bottom of the tank near the pole barriers, or near the center of the tank away from both poles. Their swimming movements were slow and unnatural. The dorsal fin was stiffly elevated.

At a current value of 14 amperes all fish swam toward the positive pole until the barrier was reached. Many tried to force their way through the protective net in their attempts to get nearer the electrode. Soon after reaching the net barrier the electronarcotic effect became evident. The fish could not

TABLE 1

MEAN TIME (IN SECONDS FOR 5 FISH, 2 TRIALS EACH) SPENT IN THE POSITIVE SECTION OF THE TANK USING UNINTERRUPTED DIRECT CURRENT

AMPERES	MEAN TIME	AMPERES	MEAN TIME
1	33.9	8	36.9
2	27.9	9	19.7
3	34.9	10	38.1
4	26.9	11	30.2
5	30.9	12	41.5
6	38.2	13	46.2
7	32.5	14	60.0

TABLE 2

MEAN TIME (IN SECONDS FOR 5 FISH, 2 TRIALS EACH) SPENT IN THE POSITIVE SECTION OF THE TANK AT VARIOUS FREQUENCIES AND AMPERAGES OF INTERRUPTED CURRENT WITH 1:1 ON-OFF RATIO

AMPERES	FREQUENCIES				
	5	10	15	20	25
1	35.0	45.8	34.6	24.3	38.2
2	30.4	31.4	33.1	42.2	28.6
3	25.0	41.5	32.5	36.8	41.0
4	28.2	33.2	46.2	48.2	43.1
5	50.3	60.0	60.0	60.0	60.0

maintain equilibrium and would sink slowly toward the bottom of the tank, ventral side up. In some, all visible signs of life, including opercular movements, ceased. However, when the power was turned off, all the fish recovered, usually within a few seconds. None died as a result of this series of tests using a constantly flowing current. Of the five fish which were tested at various amperages, one showed in both trials the complete electrotactic and electronarcotic effect at 12 amperes, one at 13 amperes, and all five at 14 amperes. Therefore, 14 amperes was considered the value necessary to cause the fish to come to the positive pole and become immobilized when uninterrupted current at 225 volts was used.

A statistical analysis of the quantitative data of Table 1 was made to supplement the observations reported above. It may be seen that the mean time spent in the positive half of the tank fluctuated between 19.7 and 38.2 seconds in the experiments conducted over a range of amperages from 1 to 11. As indicated by a "t" test, none of these means differed significantly from an expected mean of 30 seconds. At 12 amperes the mean of 41.5 seconds differed significantly from the expected mean of 30 seconds ($t = 2.06$; $P = 0.07$). At 13 amperes the mean of 46.2 seconds was also significant ($t = 4.68$; $P < 0.01$). Thus, with the aholehole, a positive electrotactic effect at a distance of 5.5 feet (the center of the tank) from the electrodes was demonstrated quantitatively at 12 amperes. However, as already pointed out, complete electrotaxis and electronarcosis did not result until a current of 14 amperes was used.

Interrupted Direct Current
1:1 On-Off Ratio

The tabulated results of experiments with various values of interrupted direct current are shown in Tables 2, 3, and 4. In the first group of experiments the power-off period was equal to the power-on period at all frequencies. Examination of the tables again discloses marked variation in the reaction of individual fish. The desired effect, which immobilized all fish at the positive pole for the full 60 seconds of each test period, was reached at an average current value of 5 amperes (Table 2). This effect occurred at each frequency with the exception of five interruptions per second. An effect comparable to this was not obtained with uninterrupted power until a current of 14 amperes had been reached. This seems to indicate that the interruption in some way of direct current makes it much more effective.

It is obvious that by interrupting the direct current so that the power alternates on and off for equal periods, more efficient use is made of the available power. The question is then raised as to whether the reaction of the fish varies with the duration of the on-or off-period. To obtain information on this

TABLE 3

MEAN TIME (IN SECONDS FOR 5 FISH, 2 TRIALS EACH) SPENT IN THE POSITIVE SECTION OF THE TANK AT VARIOUS FREQUENCIES AND AMPERAGES OF INTERRUPTED CURRENT WITH 3:1 ON-OFF RATIO

AMPERES	FREQUENCIES		
	5	15	25
4	41.9	40.3	29.4
5	38.7	37.7	22.8
6	32.3	36.2	41.5
7	52.4	52.4	52.6
8	53.7	56.5	60.0

point, the second and third groups of experiments were conducted, the results of which are given in the following sections.

Interrupted Direct Current
3:1 On-Off Ratio

The results of tests using a 3:1 on-off ratio are shown in Table 3. From this table it can be seen that the desired effect of holding the fish at the positive pole for the full time of each test was not achieved on all fish until an average current value of 8 amperes was reached, and then only in the tests having 25 interruptions per second. However, an analysis of the results shows that a significant deviation from the expected average of 30 seconds was reached in the tests using 7 amperes; for example, at five interruptions per second $t = 3.18$, $P = 0.01$. The higher amperage required when using the 3:1 on-off ratio resulted in a loss rather than a gain in the efficient use of power. It was then decided to decrease the duration of the on- (pulse) period, using a 1:3 on-off ratio.

Interrupted Direct Current
1:3 On-Off Ratio

Recorded results of these tests are shown in Table 4. A significant variation from the expected average of 30 seconds was reached at an amperage of 2. At a current value of 3 amperes and a frequency of 25 interruptions per second, all fish tested were immobilized at the positive pole. At a current value of 4 amperes all fish tested at all frequencies showed the maximum effect possible.

The quantitative data in the preceding tables do not, of themselves, indicate the full effect which results when interrupted current and decreased on-period is used. Observation of the reaction of the fish left no doubt that the experiment using the shortest pulse period produced the most violent effects. With uninterrupted current the fish's movements were slowed and inhibited. With interrupted current, as the individual shocks became shorter, the effect it produced became greater. At the shortest pulse period, with an effective current, the fish would often leap out of the water and would frequently skip along the surface, always moving directly toward the positive pole.

Variation of Response
with Frequency of Interruption

A statistical analysis was made of the relationship between frequency of interruption and time spent at the positive pole. From each group using interrupted current the recorded times at frequencies of 5, 15, and 25 were chosen. These were taken only from the two amperages just below the value that caused maximum effect (60 seconds at the positive pole). The only exception to this was the 8 ampere 3:1 on-off series; these data were added because the maximum effect was shown only in the 25 interruptions per second tests (Table 3). The following were included in the analysis: 1:1 ratio, 3 and 4 amperes; 3:1 ratio, 6, 7, and 8 amperes; 1:3 ratio, 2 and 3 amperes. The effect of different on-off ratios, as well as the effect of the various amperages, was separated by analysis of variance methods from the effect due to frequencies of interruption. The data were transformed logarithmically to conform more closely to normal distribution. The analysis provided the information given in Table 5.

There are significant differences among frequencies ($F = 6.73$; $P = 0.01$). Inspection of the data shows that the higher time averages are associated with the higher frequencies.

TABLE 4

MEAN TIME (IN SECONDS FOR 5 FISH, 2 TRIALS EACH) SPENT IN THE POSITIVE SECTION OF THE TANK AT VARIOUS FREQUENCIES AND AMPERAGES OF INTERRUPTED CURRENT WITH 1:3 ON-OFF RATIO

AMPERES	FREQUENCIES		
	5	15	25
2	41.3	44.5	55.9
3	56.3	52.0	60.0
4	60.0	60.0	60.0

TABLE 5
RESULTS OF STATISTICAL ANALYSIS OF RELATIONSHIP BETWEEN FREQUENCY OF INTERRUPTION AND TIME AT POSITIVE POLE

SOURCE	DEGREES OF FREEDOM	SUMS OF SQUARES	MEAN SQUARES
Total	20	0.243032	
Blocks	6	0.175656	0.029276
Frequencies	2	0.035628	0.017814**
Discrepance	12	0.031748	0.002645

Observation of the effect at the various interruptions leads to the conclusion that the lower frequencies are not as effective as those in the middle range. If the pulse duration is short, this is particularly true. At low frequencies there is sufficient time after the fish receives the shock to enable it to turn partially or make other movements to escape the current. As a result, the fish pursues an erratic rather than straight course toward the positive pole. In certain respects, the frequencies near the value of 15 per second have some advantages over higher frequencies used. At higher frequencies the fish receives such a rapid series of shocks that there seems to be insufficient time for it to react between shocks, thus greatly restricting its movements and slowing its progress toward the positive pole. At these higher frequencies, with an effective current, the fish often becomes immobilized at some distance from the pole.

Relationship between Average and Peak Currents

One very important fact that enters into the interpretation of the results of the experiments is that all interrupted-current values are average values. These values were adjusted to the desired reading on the ammeter while the interrupting mechanism was in operation. The peak amperage was not indicated by the ammeter during the tests because of the indicator's inertia. The peak amperage is the maximum value that will be reached during the current-on period. For example, when the on-period equaled the off-period and the average current value, as read on the ammeter, was 5 amperes, the peak current reached during each pulse was 10 amperes. This value was read on the ammeter when the interrupter was not in operation.

From Figure 5 it can be seen that the peak current in all cases is similar. It is quite possible that, were the exact current values necessary to achieve the desired effect known, the peak current in all cases might be equal. As it is, the effective average current value in

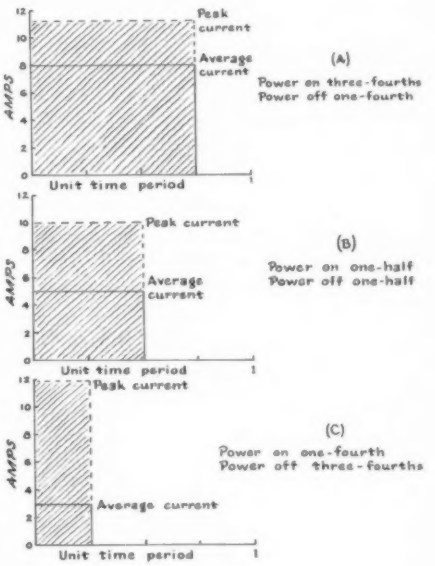

FIG. 5. Average and peak current considerations. Total power comparisons.

graph A (Fig. 5) is known only to be between 7 and 8. If the true average current values were 7.5 amperes for graph A, 5.0 amperes for graph B, and 2.5 amperes for graph C, then the peak current in all cases would be 10.0 amperes.

Decreasing the on- (pulse) period results in a more pronounced electrotactic effect at a lower amperage and also represents a saving in power. It is quite possible that further decreases in the on-time would result in equal electrotactic effects and a still greater saving in power.

The success of electrofishing in the open sea will depend mainly on the ability to make still more efficient use of available power. This is necessary because generators must be able to produce sufficient power, yet be of a size that will permit installation in a fishing boat.

The use of large amounts of electrical power presents a constant element of danger to personnel unless proper precautions are taken. Safety regulations must be strictly observed both in the laboratory and in the field.

CONCLUSIONS

1. Interrupted direct current is more desirable for electrofishing purposes than uninterrupted current because of the increased electrotactic and electronarcotic effects on the fish.
2. The use of interrupted current in electrofishing represents a considerable saving in power over the use of uninterrupted current.
3. The pulse length of interrupted current can be decreased, at least to some extent, without sacrificing any effectiveness. This results in further power savings.
4. The peak current value reached during a pulse may be the important consideration in causing the response desired in electrofishing.
5. With interrupted direct current, fish can be attracted to the positive pole and immobilized without being killed or injured.

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Biological Succession in the Aleutians[1]

THEODORE P. BANK, II[2]

WORLD WAR II provided "shock treatment" to American interest in the Aleutian Islands. Prior to 1942, the Aleutians were only vaguely known, and thought of, if at all, as cold, desolate, and totally inhospitable. This ignorance was shared by scientists, military leaders, and, too frequently, by governmental agents responsible for the administration of that part of the Alaskan Territory. A sudden awakening came when the United States and Canada were forced by the exigency of war to land and maintain a large force of men on these hitherto neglected shores, and immediately they assumed new importance as our North Pacific frontier. Attesting to this new importance is the fact that eight university-sponsored expeditions have been sent to explore the islands in the past 4 years. Greatly outnumbering these have been governmental survey parties and individual investigators. In all, more than 30 scientific projects have been directly concerned with the Aleutian Chain in postwar years. Moreover, this surge of interest seems likely to continue, as several current programs are organized on a long-term basis.

Wartime and early postwar studies were naturally concerned more with the strategic potentialities of the islands for military occupation than with purely scientific questions. However, from these investigations have come an increasing appreciation of the peculiar ecological relationship which exists between Aleutian environment and biota. Here a unique set of environmental factors has molded flora, fauna, and human culture into patterns quite different from those on most of the Mainland. This paper will outline briefly some of these patterns, which are transitional stages of biological succession.

Field work upon which this paper is based has been sponsored by the University of Michigan, the Michigan Phoenix Project, and the Office of Naval Research. In all, four trips have been made to the Aleutians, during which more than 20 islands were visited. Critically important localities such as glacial margins, hot springs, volcanic craters, and prehistoric village sites were given special attention by members of our expeditions, and an attempt was made to correlate biological and anthropological investigations with a view toward establishing a chronology of postglacial events in the Aleutians.

PLEISTOCENE PHYTOGEOGRAPHY

The most ambitious phytogeographical treatment of arctic and subartic regions in Pleistocene times is that of Dr. Eric Hultén (1937*b*). For reviews of his hypotheses, the interested reader is referred to several excellent summaries which have been published (Raup, 1941, 1947; Cain, 1944). It will be useful, however, to outline quickly Hultén's major conclusions regarding the Aleutians.

Hultén undertook extensive field work in both Kamchatka and the Aleutians, supplementing this with an examination of all available herbarium material from the arctic and

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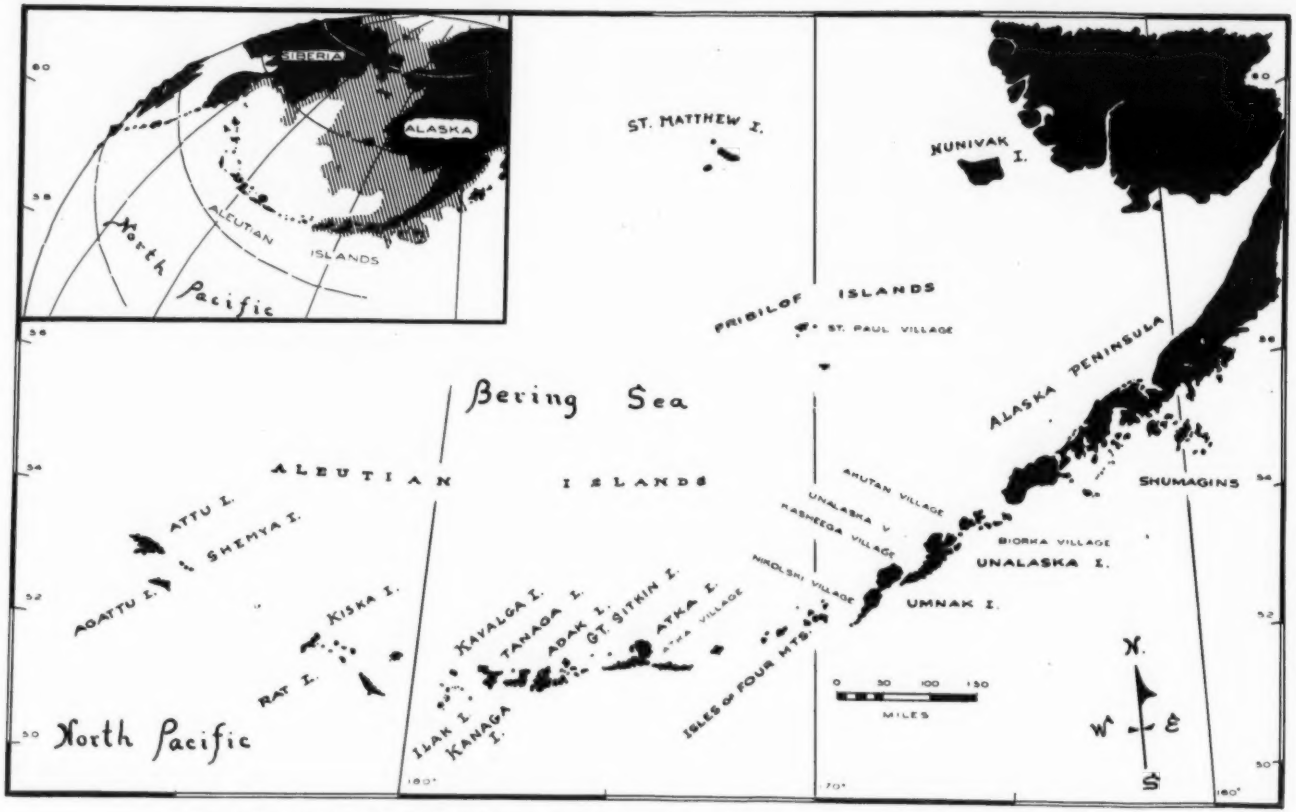

FIG. 1. The Aleutian Islands. Probable extent of ancient "Beringia" is indicated by diagonal hatching in insert.

boreal regions. Natural ranges of hundreds of plants were mapped. Ranges which were more or less congruous were grouped. Each group was thus made up of superimposed ranges which were approximately equiformal and of progressively larger area. Hultén termed these "equiformal progressive areas." He showed that each such area has a center, i.e., a region where the largest number of biotypes occurs. This is presumed to be the center of origin, and from here the plants dispersed to occupy their present ranges. Those with ranges that approximate closest the center are termed "centrants" and those with wider ranges are termed "radiants." Geographically, the centers all lie outside the maximum advance of the ice sheets and thus probably served as the major plant refuges during Pleistocene glaciation. Some plants which survived in the more extensive refugia retained their genetical ability to reproduce and quickly occupy new ice-free areas following the glacial periods. Others, on more isolated, smaller refugia, became depauperated of biotypes with the result that their spreading ability was reduced. Hultén has termed them "rigid" species. The quickly spreading plants are termed "plastic" species.

One of the most important plant refuges was an ice-free lowland which Hultén has called "Beringia," a land area thought to have existed at various times during and immediately following the Pleistocene when sufficient water was withdrawn from the ocean to expose much of the sea floor in the northern and eastern Bering Sea and southern Arctic Ocean regions (Fig. 1). From Beringia, from unglaciated portions of the eastern Aleutians and extensive ice-free areas in Kamchatka, biota surviving the pleistocene are presumed to have spread to adjacent areas as the ice withdrew. The most highly plastic species were the first to re-establish themselves on such places as the central Aleutians, which Hultén thinks were heavily glaciated and hence mostly devoid of plant life during the glacial periods. Through such differential migrations of plants from both ends of the Aleutian Arc due to unequal spreading of plastic and rigid species, the present Aleutian flora came into being. Thus, the characteristic middle-Aleutian gap which occurs in the distribution of many species (Hultén, 1937*a:* 348–381) is the result of the inability of rigid types to invade the islands as quickly as plastic ones.

Hultén's methods of arranging the equiformal progressive areas are open to certain criticisms (Raup, 1947: 231): (1) additions to his lists are undoubtedly forthcoming and may alter some equiformal areas; (2) many of the gaps in plant distribution can be shown to be gaps in exploration; and (3) Hultén's sorting of species to illustrate equiformal areas may represent a faulty technique. However, such criticism is comparatively minor, and none of the recent work has seriously altered Hultén's general hypothesis.

An example of the second criticism of Hultén's work is found in our own studies. We are now able to fill in many gaps of distribution of Aleutian plants. *Eriophorum russeolum*, for example, was supposed by Hultén not to occur between Umnak in the eastern Aleutians and Kamchatka, but we have since found it on Atka, Adak, Kiska, and Attu (Fig. 1). Likewise, *Prunella vulgaris* var. *aleutica* occurs on several islands of the middle Aleutians, where it was supposedly absent. Thus, of 105 species which theoretically have had distributional gaps in the middle Aleutians, 24 have been found on islands within the gaps. It seems likely that more will turn up as further exploration covers additional ground.

Such new and important range extensions indicate that much additional field exploration is needed. Hultén's supposition that the middle islands were heavily glaciated during the Pleistocene is not entirely correct, because subsequent work has indicated that a number of ice-free islands probably existed (U.S.G.S., 1947): for example, west of Adak, the flat, platform islands of Ogliugla, Ilak, Kavalga,

FIG. 2. Newly exposed postglacial ash profile on Tanaga Island, August, 1950. Ash, humus, and clay strata are clearly defined.

Unalaga, and Shemya, and parts of Kanaga, Tanaga, etc. These undoubtedly served as refugia for a number of hardy plants which were able to withstand the climatic rigors and the proximity of nearby ice caps on Adak, the northern parts of Kanaga and Tanaga, Amchitka, and Semisopochnoi.

POSTGLACIAL PLANT SUCCESSION

The ecological concept of succession is hard to apply to communities which continually fluctuate in an unstable way so that a so-called climax grouping today may be shown later to have been only temporary. Under such conditions, succession is difficult indeed to define and more difficult to understand, especially if brief field studies attempt to name characteristic or dominant species as criteria of certain stages. In the Aleutians what one thinks of as a successional stage or climax community is often found to consist of characteristic species which occur widely in other habitats and make up a large part of the local flora. Moreover, the community may be replaced by another during a relatively short period of time only to reappear again in slightly different form. Hultén has called attention to this by remarking (1937*a*) that the Aleutian plant associations are very similar to those of Kamchatka, but in the Aleutians the associations are much less stable. There is considerable shift back and forth in species within communities, which results in the dropping out of various members. There are also abrupt shifts in entire plant communities which result in a radically new vegetative character of a comparatively large area.

In postglacial times, as Aleutian plant life reinvaded the newly ice-free areas from various refugia, there undoubtedly occurred major disruptive phenomena which seriously in-

terfered with normal plant succession. During volcanic eruptions, for instance, large areas were completely covered by ash, and the vegetation was thus exterminated. Major ash falls are clearly marked in the soil profiles (Fig. 2). A number of such ash falls must have originated from violent eruptions which gradually diminished to a rather continuous, comparatively quiet eruption of long duration. The results of this activity appear in the profile as layers composed of coarse pumice overlaid by ash which becomes increasingly finer toward the top. These deposits are often 0.5 meters or more thick and are almost pure volcanic material devoid of any organic remains. Frequently they separate layers of almost pure humus (Fig. 3). The vegetation was destroyed by the ash fall and had to reinvade the area, in time producing the overlying humus. Thus, it is somewhat possible in the Aleutians to follow both the volcanic history and the major accompanying disruptions in plant succession.

Pollen studies of humus intercalated between ash strata offer one method of arriving at a history of postglacial plant succession, and for this purpose hundreds of soil samples were secured from various ash profiles and archaeological sites. Several of these samples have already been examined briefly for pollen by S. T. Anderson, and a preliminary report of the results has been released (Anderson and Bank, 1952). These are interesting and worth summarizing. Two humus samples from soil strata, one at 0.92 meters depth and the other at 1.83 meters depth, came from a single ash profile on Tanaga Island in the middle Aleutians. Usually, terrestrial ash-soil deposits should not contain much pollen, as the grains would ordinarily be destroyed by oxidation. It was therefore somewhat surprising to find that these samples contained sufficient pollen for quantitive studies. This is probably because of the unusual Aleutian climate, marked by consistently high precipitation and fairly low soil temperatures. Many Aleutian soils are constantly saturated with water, which undoubtedly is a major factor in the preservation of pollen and spores.

The samples were treated according to the procedure described by Faegri and Iversen (1950). Pollen from the lower part of the profile represents an entirely different plant community from that of the upper part. The

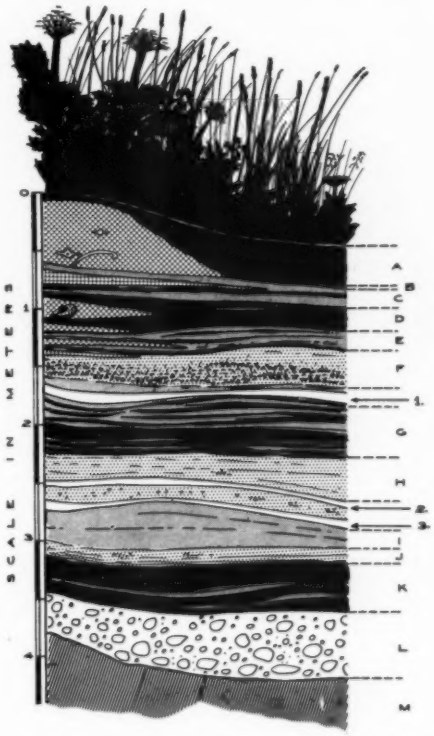

FIG. 3. Diagrammatic profile at the edge of an Aleut kitchen midden on Nazan Bay, Atka Island. Vertical and diagonal cross-hatching indicates clam shell, fish bone, and sea urchin shell deposits (archaeological). Also shown are sea lion bones and a stone lamp in position. The nonarchaeological strata are: A, recent humus; B, sand; C,E,I, fine ash, slightly stratified; D,G,K, humus with fine ash admixture, stratified; F, H,J, coarse pumiceous ash; L, brown clay with large pumice (till ?); M, bedrock; 1,2,3, ferruginous bands (from leaching from above?). Surface vegetation, especially lush on such sites, is indicated and includes: *Heracleum lanatum*, *Elymus arenarius* subsp. *mollis*, *Conioselinum Gmelini*, *Angelica lucida*, *Aconitum maximum*, *Claytonia sibirica*, *Achillea borealis*, and *Calamagrostis canadensis* var. *Langsdorffii*.

older pollen and spores consist of high percentages of *Ericales* (55 per cent), Gramineae (22), and *Lycopodium* (17), with some Cyperaceae (2.9). Thus, the lower sample represents the *Empetrum* heath of higher altitudes (Hultén, 1937*a;* Bank, 1952). The younger pollen and spores show high percentages of Gramineae (56), Cyperaceae (23), and Ranunculaceae (9.0), with some *Ericales* (3.7), *Dryopteris* (3.1), and Umbelliferae (2.2). This sample indicates a vegetation very similar to the *Calamagrostis* meadow which exists today at the place of the profile.

The results of this preliminary pollen study are, of course, inconclusive. What they do indicate is that pollen analysis of at least some strata in Aleutian ash profiles is possible. Certain changes in vegetation are indicated, i.e., from an earlier *Lycopodium-Empetrum* heath to a *Calamagrostis*-Umbelliferae meadow, and these changes can be interpreted as due to climatic fluctuation from dry, continental-arctic to moist, oceanic-subarctic. However, great dependence upon pollen shifts at isolated sites as an indication of widespread climatic changes is extremely hazardous for two main reasons: (1) it seems likely that heavy ash falls not only destroyed existing vegetation but also produced such radical changes in the local habitat that the succeeding vegetation may have been of totally different character for edaphic reasons; and (2) the normal instability of Aleutian biota, to which I have already called attention, operates to produce major changes in natural biotic groupings for reasons much less basic than climatic interference.

Raup (1950) has discussed this latter general problem of physiographic ecology in arctic and subarctic regions. He says (p. 8): "Approaches to equilibrium or relative stability such as we find in the temperate regions and are wont to call climax, are almost impossible to define in the Arctic and much of the Subarctic. At best they are ephemeral in time and space." And again (p. 10), ". . . it becomes apparent that one of the prime requisites for development of dominance and succession—long continued stability in the substratum—is absent or very poorly represented over vast areas in the Arctic and Subarctic."

An example of a constantly unstable substratum in the Aleutians is found in the alpine regions where the unceasing wind, more than any other ecological factor, restricts plant growth, molds vegetational structure so to speak, and, when aided by subsurface water, often radically changes the vegetational character of large areas in a comparatively short period of time. Thus in high, exposed places one frequently comes upon bare patches of gravel or ashy soil having a slight ridge along the lower margin. These areas are wet and are usually on slopes. Underground seepage has saturated the soil, which lies thinly over bedrock, with the result that large soil patches have flowed downhill carrying vegetation with them. Surface water further erodes these areas, and wind removes all loose plant fragments. The bare patches may be reinvaded by plants, but irregular shallow depressions in the surface of the vegetational mat identify the spot as a former slough area. Frequently these are continually eroded by the high winds, and scalloped gravel pits are formed. The gravel-blasting effect of the wind prohibits all but the hardiest plants from gaining a foothold. At first only gnarled, almost leafless, dwarfed (6 inches tall) willows may grow. In time these eroded patches are probably covered by willows and lichens, which in turn offer some protection from the wind to less hardy plants, among them *Campanula lasiocarpa*, *Primula cuneifolia*, *Antennaria dioica*, and *Polygonum viviparum*.

Probably the best examples of vegetational instability are found in the wet habitats. Often these develop in the middle of an otherwise dry Aleutian meadow or heath area. In such places subsurface water may begin to seep from the hillside and form bog-like drainage slopes on which a number of bog plants, especially *Sphagnum*, begin to grow. Soon

FIG. 4. Temporary bog in the middle of a lowland meadow, Atka Island. Seepage from surrounding hillsides collects here, and plants typical of wet habitats invade the area. These plants include: *Carex Lyngbyaei* and other *Carex* spp., *Plantago macrocarpa*, *Polygonum viviparum*, *Platanthera dilatata*, *Juncus balticus*, *Erigeron perigrinus*, *Eriophorum Chamissonis*, etc.

these areas are inhabited by liverworts, *Sphagnum capillaceum*, *S. Girgensohnii* and other mosses, *Saxifraga punctata* subsp. *insularis*, *Leptarrhena pyrolifolia*, *Viola Langsdorffii*, *Pinguicula vulgaris*, sometimes *Scirpus* spp., and *Carex* spp. Their growth often becomes extensive and deep enough to necessitate a wide detour when walking across a hillside. These are usually temporary features, however, and such wet places, with their typical vegetation, constantly appear and disappear under the influence of fluctuating subsurface drainage patterns, which are in turn greatly affected by yearly variations in snow accumulation. True peat bogs, such as those common to parts of mainland Alaska and Canada, are not found in the Aleutians. Instead the bogs are of the type just described, formed from seepage, or are essentially low areas containing water-saturated mud overlaid by scattered growths of sedges, *Juncus* spp., short grasses, and sometimes *Sphagnum* (Fig. 4). Usually such areas are shallow, but some are deep enough to completely mire large vehicles. Many such mud bogs are only a transitional stage for shallow ponds and meadows. I observed an amazingly quick replacement of *Carex Lyngbyei* and *Eriophorum Chamissonis* by *Calamagrostis canadensis* var. *Langsdorffii* and other grasses after one such bog was drained by military operations.

Other evidences of instability are noticeable in stream ravines. Usually occurring here are ferns (*Athyrium Filix-femina* and *Dryopteris* spp.), grasses such as *Deschampsia beringensis*, mosses, *Streptopus amplexifolius*, *Epilobium angustifolium* var. *macrophyllum*, frequently *Artemisia unalaskensis*, and various umbellifers. The profuse vegetation frequently grows out over the stream and in time may entirely cover

FIG. 5. Diagrammatic profile of part of a typical "slumped" stream bed and underground channel. Such stream tunnels, A–C, are fairly common in the Aleutians and can be dangerous should a person fall through the ceiling B. The lower outlet A and the upper entrance C are usually choked with ferns and other plant growth. The tunnel ceiling usually possesses a meadow vegetation, consisting of grasses, umbellifers, *Streptopus*, *Claytonia*, etc. At D a series of terraces are formed from a former tunnel ceiling which slumped gradually and finally caved in. The vegetation here is usually bog-like, with *Sphagnum*, *Carex*, *Juncus*, liverworts, and *Saxifraga* predominating.

the ditch so that the stream flows through an underground tunnel (Fig. 5). These places can be quite dangerous. Hultén (1937*a*) mentions falling through the ceiling of one such tunnel. Hidden streams may persist this way for a considerable time, but usually the overhanging mat is penetrated by surface drainage, holes reappear, the overhanging mat slumps, and the ditch becomes a series of depressions or wet terraces composed of sphagnum and typical bog plants, a much different vegetation than that which formerly occurred in the ravine.

In the Aleutians, this instability of substratum and plant cover does not have precisely the same causes as on the mainland. Permanent subsurface ice (permafrost), for example, is not the very important factor that it is over widespread areas of Siberia, mainland Alaska, and Canada. Rather, instability is probably a result of the interaction of the edaphic and climatic factors which make the Aleutians more or less unique: namely, a comparatively thin soil mantle largely of volcanic ash, more or less continuous ash deposition, temperate conditions with heavy precipitation, cool summers, and unusually high, rather constant winds.

Kellogg and Nygard (1951) have characterized the Aleutian substratum as "tundra without permafrost" and composed of silty or sandy loam with ash. There are, however, small areas of permanent subsurface ice in the Aleutians which may be fairly extensive albeit sporadic and seemingly of little influence on surface vegetation. I observed one such area on Great Sitkin Island where Glacier Creek has cut through an ancient mud flow. Ice is exposed in the profile about 20–30 feet below the surface of the old flow. Thick sheets and occasional lenses of ice can be traced along the floor of the stream bed for distances of 25 to 50 yards. Strictly speaking this is not permafrost but relict glacial ice. The surface topography and vegetation are unmodified, and it is presumed that the depth at which the ice occurs is too great to affect plant growth above. Melting of the ice masses, however, will undoubtedly cause local land slumps leading to the formation of kettles and, thus, different microhabitats which will have their peculiar plant communities.

RECENT PLANT INVASIONS

The foregoing examples of fluctuating vegetation in the Aleutians illustrate the spreading ability, i.e., plasticity, of some plants of this area. This ability has been noted by Hultén (1937*b*) who writes that on Bogoslof, the "jack-in-the-box" island that has appeared and disappeared a number of times in the last 150 years, a pioneering vegetation is already well established. It includes *Lathyrus maritimus*, *Elymus arenarius* subsp. *mollis*, *Honckenya peploides major*, *Puccinellia pumila*, and *Mertensia maritima*, all of which are widespread littoral plants. *Senecio pseudo-arnica* also occurs on the still-warm shores. Our own field parties studied briefly several pioneer plant communities near a small glacier on the upper

slopes of Great Sitkin Island (Fig. 1). We visited the place on two occasions 12 months apart. It was noted in 1950 that during the preceding year a considerable extent of newly ice-free area had been successfully invaded by a number of plants, mostly mosses and lichens but also including *Luzula arcuata*, *Agrostis exarata*, *Hieracium triste*, *Carex circinata*, and *Sibbaldia procumbens*. Although the actual creep of vegetation was in most cases only a few feet, this was all along the margin of the newly exposed ash, a sizeable area, and seems remarkable for having occurred during a single growing season.

Contrasting with this is the inability of *Picea* to establish itself on Aleutian soil, despite the fact that extensive spruce forests occur on the mainlands of Alaska and Kamchatka at the same latitudes. On Amaknak Island in Unalaska Bay in 1805 Russian settlers planted 24 seedlings of *Picea sitchensis* which came from Sitka (Hultén, 1937*a*). Other Sitka spruces were later planted on Expedition Isle in Roose Bay and in Unalaska Village. All these groves have been depleted by dying trees, but parts of the original plants are still alive, and, except for the stunted appearance and gnarled form of some of the trees, they seem healthy. Many regularly produce cones. However, none has successfully reproduced by seedlings. More recently, at Adak, several dozen Sitka spruces were planted on a hill and on a lowland. These plantings are failures; the trees that have survived are stunted, and there has been no reproduction.

Such lack of success on the part of the spruce in taking hold in the Aleutians has been attributed to various causes, among which the acid soil conditions, high winds, and constant fog are most often given. None of these answers satisfactorily explains the real reasons why the trees fail to grow in the Aleutians, however. The so-called extreme acidity of Aleutian soils is probably a misconception (Kellogg and Nygard (1951) have found that soil *p*H in the Aleutians is about the same as that on Kodiak where there are spruce forests), many of the planted groves are fairly well sheltered from the winds, and it is difficult to see how fog could prohibit tree growth entirely. I can only guess at the true reasons, as the proper studies have not been made. It is suggested that the primary ecological factor operating against spruce regeneration is the absence of any prolonged summer period of uniformly high enough temperatures to allow maturation of seed.

CULTURAL SUCCESSION

Turning from a discussion of the effects of Aleutian environment upon biological succession to a brief consideration of the ways in which human culture has been conditioned by the same environment, we find that the Aleut was confined to a rather restricted range of cultural adaptations, which depended upon the sea and the shore. The Aleut seldom visited the inland regions of his islands, partly because topography and weather factors in those parts made such journeys a hardship, but mainly because the majority of his needs were found only on the shore, in the lowland meadows, valleys, and marshes near the sea, or in the sea (Bank, 1952). Of more than 50 local plants which the Aleut gathered for food, drink, medicines, and for use in the manufacture of such articles as grass mats, baskets, bidarki (kyak) frames, etc., almost all occurred along the margins of the islands. The Aleut depended upon fish, sea mammals, shell fish, and birds for food, and these also came from the sea or near the shore. Thus, even if Aleut culture had not been predominately maritime prior to its arrival in the Aleutians, it certainly was unable to be anything else after the Aleut took up his habitation in the Archipelago. Recent archaeological studies (Jochelson, 1925; Laughlin, 1951) have shown that Aleut culture changed only slightly during 3,000 years of occupation in the islands before the coming of the white man.

Early Russian accounts (Jochelson, 1925: 23) suggest that Aleut villages were on exposed points of land and isthmuses prior to

1741. This was because survival of an attack of a stronger warring party required access to an escape route by sea on more than one side. After the Russians had put an end to inter-island warfare, the villages were supposedly moved to sheltered bays which offered many advantages of improved fishing and better harbors. This view is somewhat substantiated by vegetational patterns, for old villages located on points of land (thus presumably pre-Russian) usually possess a comparatively less dense plant cover than do old villages located in bays. The latter sites (presumably more recently abandoned) often have a particularly lush plant cover.

However, an outright assumption that the oldest sites are to be found on points of land or isthmuses along the coasts should not be made. It is known that the islands have been rising throughout the history of the Archipelago. Jaggar (1908: 32) mentions finding old beach terraces on Unalaska at 130 meters altitude. Veniaminof (Petrof, 1884: 148) and Hultén (1937*a*: 24) also call attention to old shore lines, and more recently they have been reported by members of the U. S. Geological Survey field parties (U.S.G.S.,1947: 102). These places have not been explored archaeologically, although Hrdlička (1945) mentions several village sites in the eastern part of Agattu at a considerable distance above the sea, and I have also noted from the air an old village situated on a cliff high above the sea in the western part. It is entirely possible that future reconnaissance will uncover the oldest sites on such uplifted beaches, and it may be that here is where the true beginning of Aleut culture will have to be sought.

SUMMARY

Study of biotic patterns in the Aleutians shows them to be extremely unstable. There are frequent vegetational shifts which results in a totally new plant cover over comparatively large areas. In postglacial times some of these shifts may have been caused by climatic changes, but it is believed that most of them have come about through unstable soil conditions, which in turn have been influenced by fluctuations in seasonal weather. Wind is a very important factor determining vegetational structure and composition at higher altitudes. Any semblance of normal plant succession as it is known in similal latitudes on the mainlands of Asia and America is frequently altered by the combined effects of volcanic ash eruptions, wind erosion, periodic moisture surpluses (after heavier-than-usual winter snowfalls), etc. In general, vegetation is much less stable and biological succession more erratic in the Aleutians then on the mainlands. This is in sharp contrast to Aleut culture, which apparently remained unchanged in most of its major aspects during 3,000 years of existence in the Aleutians.

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New Alaskan Records of *Eurytemora* (Crustacea, Copepoda)

MILDRED STRATTON WILSON[1]

THE COPEPOD GENUS *Eurytemora* is known from all the coastal areas of North America, though the records are not extensive. The species occur in salt, brackish, and fresh water. As the genus is widely spread throughout the northern regions of the world, it is to be expected that the coastal areas of Alaska would have an abundance of all the habitat forms. Unfortunately, in the Alaskan collections made during the Canadian Arctic Expeditions no mature specimens were found (Marsh, 1920: 4j). The present report is therefore of interest in recording two species from western Alaska. These include a fresh-water form new to science and an Asiatic brackish-water species not before known in North America.

I am indebted for these collections to Dr. Clifford O. Berg of the Arctic Health Research Center and to Mr. Frank P. Pauls of the Alaska Department of Health. Specimens of each species have been deposited in the United States National Museum.

Eurytemora yukonensis n. sp.

Figs. 1–5

SPECIMENS EXAMINED. Four lots, fresh water, lower Yukon River area, western Alaska. C. O. Berg, collector.

Type lot: 25 ♀ (many ovigerous); 13 ♂; many copepodids. Wilson Creek, about a mile southeast of Fortuna Ledge (formerly and popularly known as Marshall), July 27, 1951. Holotype ♀, U.S.N.M. 93268; allotype ♂, U.S.N.M. 93269.

Lot 2: 4 ♀, 5 ♂, many copepodids. Near outlet of stream into Yukon River, about ¼ mile north of Fortuna Ledge, July 28, 1951.

Lot 3: 4 ♀, copepodid stage V. Small lake southwest of Holy Cross, June 15, 1951.

Lot 4: 7 ♀, 8 ♂, 4 copepodids. Widened portion of stream emptying into Andreafsky River, about 1 mile east of Andreafsky, August 16, 1951.

Female: Total length, dorsal mid-line, 1.645 mm. (metasome 1.01 mm., urosome 0.635 mm.). Head rounded, body tapering, the greatest width in segment 2 (0.415 mm.); width of segment 5, 0.34 mm. First segment showing in lateral view (Fig. 1) a pronounced cephalic depression and a prominent medial distal protuberance. "Wings" of last segment very wide, slanting outward, without pronounced inner lobes, entire expanse greater than width of second segment (0.48 mm.).

Urosome equaling 38 per cent of total length. Relative lengths of segments and caudal rami, exclusive of caudal setae:

1	2	3	CR
50	33	45	61

Genital segment constricted in middle, a little asymmetrical, both proximal and distal lobes prominent, proximal wider than distal, both armed with a few lateral sensory hairs. Genital operculum small, nearly hemispherical, distal edge quite rounded. Segments 2 and 3 without ornamentation.

Caudal rami shorter than segments 2 and 3 combined, their length about 5.5 × their width; unarmed except for inner marginal

[1] Arctic Health Research Center, United States Public Health Service, Federal Security Agency, Anchorage, Alaska. Manuscript received October 10, 1952.

hairs. Longest of caudal setae equaling length of rami.

Antennules 24-segmented, reaching to near end of metasome segment 5. Division between segments 8 and 9 distinct on inner side, but not always on outer. Aesthetes with stalk-like bases (Fig. 2). Setae not long, none reaching farther than to near end of succeeding two segments. Numerical setation as follows (s—seta, sp—spine, a—aesthete):

Segment		
	1—3s, a	13—2s
	2—3s, a	14—2s, a
	3—2s, a	15—2s
	4—ls	16—2s, a
	5—2s, a	17—2s
	6—ls	18—2s
	7—2s, a	19—2s, a
	8—sp	20—ls
	9—2s, a	21—ls
	10—sp	22—ls+ls
	11—2s, a	23—ls+ls, a
	12—ls, a, sp	24—6s, a

Mandible blade (Fig. 5) with anterior side rounded, produced to moderately sized denticle with small transparent cap; symmetrical, moderately deep gap present between it and following denticle.

Leg 5 (Fig. 2) having basipod and exopod subequal in length. Lateral spines of exopod 1 short, not as long as width of segment, tips sinuous. Inner process nearly straight, forming right angle with segment, its width greater than length of segment (22:15, measured from notch at inner lower base); margins serrate. Terminal inner spine of exopod 2 as long as total exopod, proportion to outer lateral spine 25:7; segment produced to minute point between the two spines; inner margin of segment with two extremely fine hairs.

Male: Total length dorsal mid-line 1.38 mm. (metasome 0.81, urosome 0.57 mm.). First segment with cephalic depression and prominent medial dorsal protuberance as in female.

Urosome 41 per cent of total length of body. All segments lacking ornamentation. Caudal rami a little shorter than segments 3–5 combined, about 35 per cent of total length of urosome; their length about 7 × their width. Rami unornamented, except for long hairs on inner margins. Longest caudal setae longer than rami.

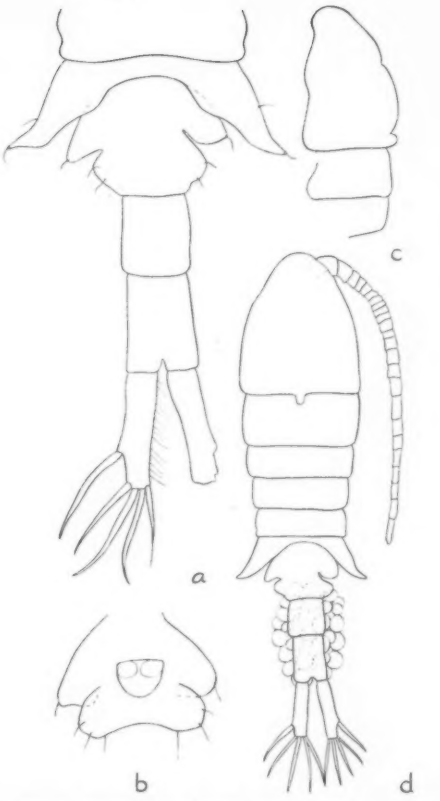

FIG. 1. *Eurytemora yukonensis* n. sp. Female. *a*, Metasomal segment 6 and urosome, dorsal view; *b*, genital segment with operculum, ventral view; *c*, habitus, lateral view of cephalic segment; *d*, habitus, dorsal view.

Antennules reaching a little beyond metasome. The left differing from that of female in having only 1 seta on segment 11, and in having aesthetes on all of segments 1–19, except on 4. Aesthetes longer than in female, those of segments 12 and 14 particularly long, reaching to about end of following two segments. Right antennule with spines on segments 8–12, length of all less than width of

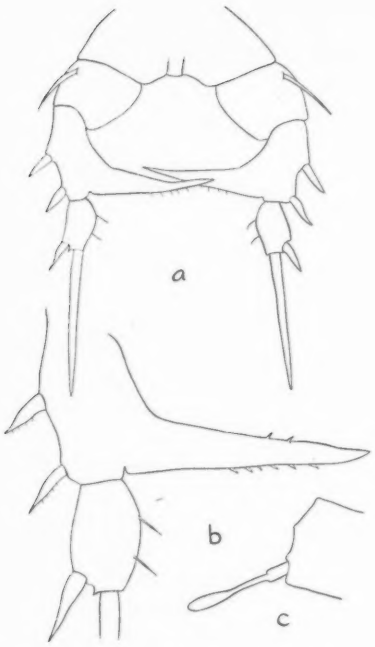

FIG. 2. *Eurytemora yukonensis* n. sp. Female. *a*, Leg 5; *b*, leg 5, detail of armature of exopod segments 1–2; *c*, antennule, aesthete of segment 11.

segments, those of 9 and 12 longest, subequal to each other (Fig. 3). Segments 14–16 very swollen. Segments 17 and 18 with marginal, hyaline, depressed processes ornamented with double row of spinous serrations. Penultimate segment with proximal curving group of long, slender spinules, with striated lamina following; distal portion without ornamentation. Terminal segment somewhat longer than preceding segment (50:40).

Leg 5 (Fig. 3) having both rami 4-segmented. Basal portion narrow, first segment of left leg longer than that of right. Right leg characterized by an extremely long terminal segment. Relative lengths of basipod 2 and exopod segments 1 and 2: 40:50:73. Inner distal portion of second basipod segment swollen a little. Terminal segment not only extremely long but very slender, without any inner basal swelling, and with distal inner margin very irregular.

Second basipod segment of left leg short, swollen inside. Terminal segment a little longer than exopod 1 (45:40), apex broadened but hardly produced on either side; inner portion and most of anterior side set with short hairs.

COPEPODID STAGES (Fig. 4). Copepodid stages 3, 4, and 5 were present in the collections. All had a prominent dorsal protuberance of the cephalic segment as in the adult. Stage V is briefly described.

Female, stage V: Total length 1.29 mm. (metasome 0.8, urosome 0.49 mm.). Urosome 3-segmented, genital segment without lateral protrusions. Proportion of caudal rami to rest of urosome 12:20. Antennule 23-segmented. Leg 5 having inner process of exopod short, lateral spines all short as in adult, terminal spine also about as long as exopod, spinous process between terminal spines more pronounced than in adult.

Male, stage V: Total length 1.175 mm. (metasome 0.725, urosome 0.45 mm.). Urosome 4-segmented. Leg 5 with 4-segmented rami, left a little shorter than right, apical segments very similar, others showing a slight asymmetry, most pronounced difference being rounded protrusion of inner margin of right basipod 2.

DIAGNOSTIC CHARACTERS. The diagnostic characters of this species may be summarized as follows:

Pronounced dorsal protuberance of cephalic segment in both sexes in adult and copepodid stages 3–5.

Genital segment of female strongly constricted, proximal lateral lobes wider than distal; genital operculum hemispherical.

Urosome and caudal rami in both sexes lacking dorsal ornamentation.

Caudal rami of female shorter than segments 2 and 3 combined; those of male shorter than segments 3–5, their length about 7 × their width.

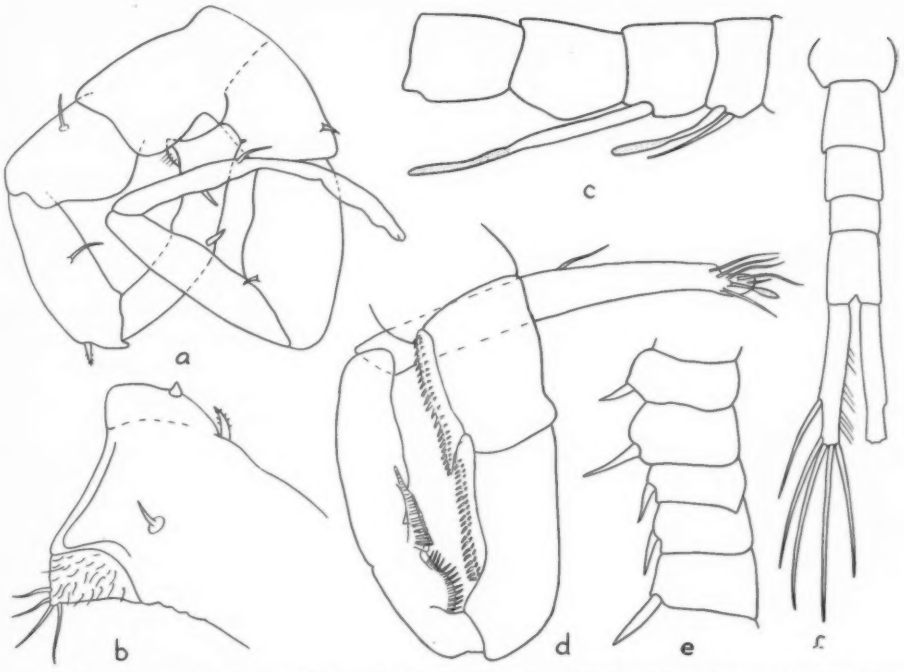

FIG. 3. *Eurytemora yukonensis* n. sp. Male. *a*, Leg 5, posterior view; *b*, leg 5, detail of apex of left exopod, posterior view; *c*, left antennule, segments 11–13, with detail of aesthetes; *d*, right antennule, apical segments; *e*, right antennule, segments 8–12, with detail of spines; *f*, urosome, dorsal view.

Mandible blade with symmetrical gap between anterior edge and succeeding denticle.

Spines on segments 8–12 of right antennule of male shorter than width of segments, those of 9 and 12 longest.

Leg 5 of female with 2 spines on exopod 1; inner process straight, wider than length of segment; lateral spines short. Inner terminal spine of exopod 2 as long as whole exopod; this segment with inner hairs.

Leg 5 of male with both rami 4-segmented, claw of right side very much longer than preceding segment (73:50). Terminal portion of left leg expanded but without digitiform protrusion.

COMPARISON WITH OTHER SPECIES

The fifth leg of the female most closely resembles that of *Eurytemora lacustris* Poppe (as described by Sars, 1903). It further agrees with this species in lacking dorsal ornamentation on the urosome and caudal rami. It differs in having the last metasomal segment produced into conspicuous wings and the genital segment swollen and constricted laterally. The left fifth leg of the male of *yukonensis* differs from *lacustris* in not having the terminal portion produced into a prominent digit.

Eurytemora composita Keiser

Figs. 5–7

Eurytemora composita Keiser, 1929: 301, figs. 1–6.

Eurytemora composita Smirnov, 1929: 318, figs. 1–2.

Eurytemora composita Rylov, 1930: 234, fig. 77 (after Keiser).

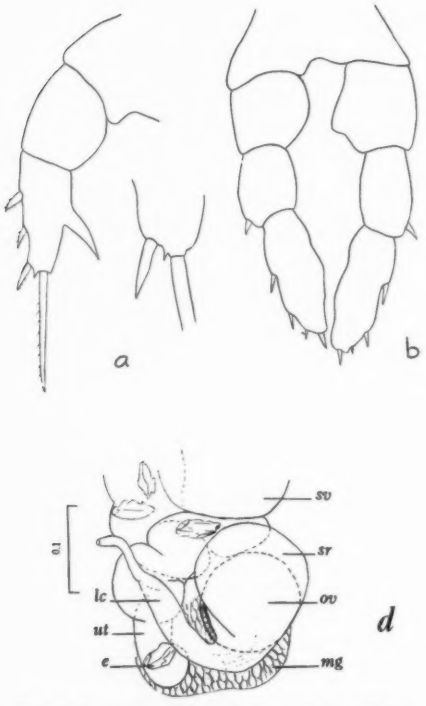

FIG. 4. *Eurytemora yukonensis* n. sp. Copepodid stage V. *a*, Female, leg 5 with detail of apex of exopod; *b*, male, leg 5, posterior view.

?*Eurytemora* spec. Kiefer, 1938: 78, figs. 1–3 (♂).

SPECIMENS EXAMINED. One ♀. Tundra pond (brackish?) near Unalakleet, on Norton Sound, western Alaska, August 7, 1951, C. O. Berg.

Five ♀ (4 ovigerous), 8 ♂, 21 copepodids. Pond (fresh water which might become brackish at times), Boxer Bay, southwest cape of St. Lawrence Island, Bering Sea, Alaska, July 6, 1952, F. P. Pauls.

DESCRIPTION OF ALASKAN SPECIMENS.

Female: Total length dorsal mid-line: St. Lawrence Island specimens 1.21–1.46 mm.; Unalakleet specimen 1.41 mm. (metasome 0.68, urosome 0.55 mm.). Body form in dorsal view similar to that of *yukonensis*. Relative lengths of the segments:

1	2	3	4	5	6
110	50	40	32	15	9

Greatest dorsal width of metasome in segments 2 and 3 (Unalakleet specimen 0.37 mm.; reduced to 0.295 mm. in segment 5). First segment in lateral view (Fig. 6) showing no cephalic depression or medial dorsal protuberance. Wings of sixth segment a little asymmetrical, each with well-developed, rounded inner lobe; outer portion produced into outwardly and backwardly directed protrusions reaching about to middle of genital segment and armed with scattered hairs.

Urosome equaling 39 per cent of total length. Relative lengths of urosome segments (mid-line) and caudal rami, exclusive of setae:

1	2	3	CR
46	27	31	60

Genital segment constricted in the middle, upper part with nearly symmetrical, rounded lobes produced laterally beyond those of distal part, armed marginally with hairs. Genital operculum conspicuous in lateral profile (Fig. 6*d*), occupying a comparatively large part of ventral area which is without cuticular folds or tumid protrusions. A heavy, sclerotized, semicircular line encloses area of receptacula, portion of operculum distad to this consists of a large, rounded flap.

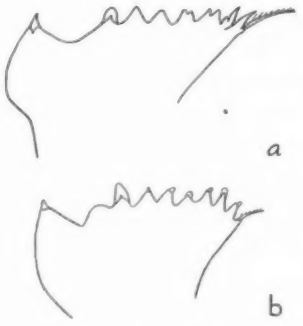

FIG. 5. Apex of mandible blade, female. *a*, *Eurytemora yukonensis* n. sp.; *b*, *Eurytemora composita* Keiser.

Dorsal surface of segments 2 and 3 spinulose except in medial portion.

Caudal rami subequal in length to segments 2 and 3 combined; length about 6 × their width (measured without pressure); their dorsal surface entirely covered with short, stiff hairs extending over outer margin to base of lateral seta; inner margin with closely set long hairs. Inner terminal seta longest, equaling length of ramus.

Antennules shorter than metasome, reaching to about middle of fifth somite; 24-segmented, segments 8 and 9 imperfectly separated. Setation typical as in female of *yukonensis*, aesthetes on narrow basal stalks. Setae comparatively long, particularly on segments 7–20; those of 15 and 20 longest, those of 15 of nearly uniform length, reaching to near end of or beyond segment 18.

Mandible blade (Fig. 5) having anterior edge produced to a large triangular tooth, usual gap between it and succeeding denticle filled by a rounded protuberance.

Leg 5 (Fig. 7*d*) having exopod (exclusive of spines) only a little longer than basipod, 25:20. Spines of exopod 1 longer than width of proximal part of segment. Lateral spine of exopod 2 nearly as long as terminal inner spine. Relative lengths of spines to one another:

Segment 1	Segment 2
9 : 11	13 : 18

Exopod 1 not quite twice length of exopod 2 (16:9). Inner process, measured from inner base of segment 2, a little longer than total length of its segment (19:16); tips markedly upcurved, margins with a few exceedingly fine serrations. Lateral spines appearing unarmed except under high power which shows that their margins are also minutely serrate. Terminal inner spine of exopod 2 relatively short, about twice length of segment which is not produced to a spinous point between it and lateral spine. Two very fine hair-like setae on inner margin of segment.

Male: Total length dorsal mid-line about 1.07 mm. (metasome 0.605, urosome 0.465 mm.). Cephalic segment in lateral view showing no depression or distal protuberance. Last segment not produced laterally, armed with a few hairs.

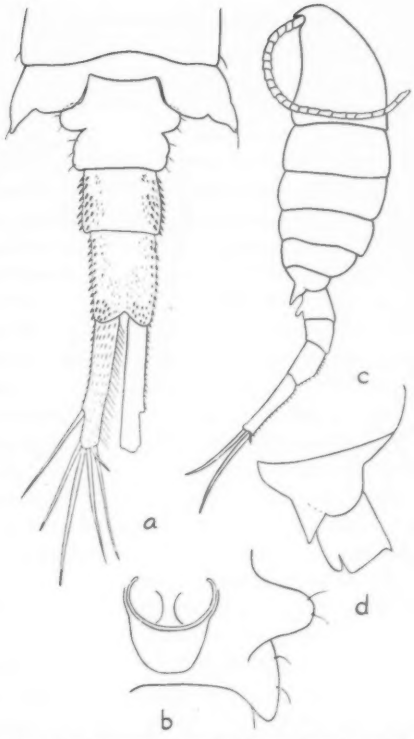

FIG. 6. *Eurytemora composita* Keiser. Female. *a*, Metasomal segment 6 and urosome, dorsal view; *b*, operculum and lateral outline of genital segment, ventral view; *c*, habitus, lateral view; *d*, outline of metasomal wings and genital operculum, lateral view.

Urosome (Fig. 7) 43 per cent of total length of body. Segments 1–4 armed laterally with scattered hairs, segment 5 with short spinulose hairs on outer dorsal surface and lateral margins.

Caudal rami (exclusive of setae) a little longer than segments 3–5 combined; equaling about 39 per cent of total length of urosome; their length nearly 10 × their greatest width. Outer margin with closely set coarse hairs which may or may not extend onto dorsal

surface in area of lateral seta; in an individual, this dorsal ornamentation may be present on one ramus but not on the other. Inner margin with long hairs. Terminal inner setae longer than caudal rami (about 70:58).

Left antennule with setation typical, differing from that of female in having 1 seta on segment 11, and in having aesthetes on all of segments 1–19, except on segment 4; aesthetes also considerably longer, as in *yukonensis*. Right antennule with segments 12–16 very swollen. Segments 8–12 with spines, all of which are shorter than width of segments; those of 9 and 12 only a little longer than the others. Terminal segments armed as in *yukonensis*. Apical segment only a little longer than the preceding.

Mandible as in female.

Leg 5 (Fig. 7*a*) having left basal portion wider than right and with an inner protrusion. Right second basal segment enlarged, its greatest width to length 20:30, without marked inner protrusion. Right exopod 2-segmented, first segment only a little longer than basipod 2, but much narrower. Terminal segment longer than exopod 1, 47:35; inner basal portion without a conspicuous swollen portion; terminal part with cuticle of both margins irregular. Left leg having second basal segment shorter than that of right side, without marked inner protrusion. Exopod 2-segmented, both segments with a stout outer spine; terminal segment longer than the first, 45:30. Apical portion of segment 2 broadened, outer part extended as a swollen, rounded digit, tipped with small seta; inner portion having cuticle crenate, anterior side with pad of thickly set fine hairs which protrude beyond margin.

COMPARISON OF ASIATIC AND ALASKAN FORMS

Eurytemora composita has been known only from the type locality, Lake Issyk-Kul, a large, brackish lake in western Turkestan. Some of Keiser's specimens were examined by Smirnov, who supplemented the description of the type material, giving a more exact illustration of the male fifth leg. Since the two descriptions otherwise agree very well, it may be assumed that the Asiatic form is well enough known to compare it with the Alaskan form with some degree of certainty. The details of the antennules and mandible are not known for the typical form.

The Asiatic and Alaskan females exhibit the following similarities, all of which are diagnostic characters of the species:

Size—1.2–1.4 mm.

Metasomal wings produced, with inner lobes.

Genital segment with lateral hairs, constricted medially, with prominent, symmetrical, proximal lobes.

Genital operculum rounded distally, receptacula located above medial sclerotization.

Anal segment and caudal rami with dorsal ornamentation.

Caudal rami subequal to segments 2 and 3 (or a little longer), length 6 × their width.

Shape and relative proportions of segments and spines of leg 5.

Presence of inner setae on exopod 2 of leg 5.

The Alaskan female differs from the typical form in:

Presence of dorsal ornamentation on second segment of urosome.

Possible greater development of genital operculum.

Leg 5—Upcurved tip of inner process of exopod 1 and presence of two slender hair-like setae rather than a single stout seta on inner margin of exopod 2.

No illustration of the male urosome has been given for typical *composita*, but Keiser states that the length of the rami is 7 × their width, and that hairs are present only on the inner margin. The Alaskan specimens differ in having the length of the rami about 10 × their width, and in the presence of hairs on the anal segment and on both margins of the rami. The fifth leg appears to be very similar in the proportions of the segments and the structure of the apical part of the left leg.

Kiefer's brief description of two males from Paramushir Island in the Kuriles of northern Japan agrees in most points with *Eurytemora composita*. It is like the Alaskan form in having hairs on the anal segment. There are some slight differences in the fifth leg, though the proportions are similar. Without knowing the characters of the female, it would not be entirely correct to ascribe Kiefer's specimens to *composita*. However, the widely separated Turkestan and Alaskan localities suggest the probable occurrence of the species in intermediate places.

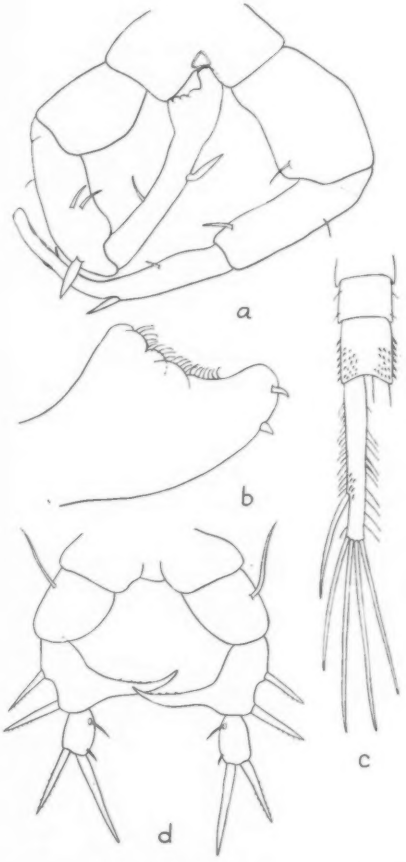

FIG. 7. *Eurytemora composita* Keiser. *a*, Male, leg 5, posterior view; *b*, male, leg 5, detail of apex of left exopod, posterior view; *c*, male, urosomal segments 4–5 and caudal ramus; *d*, female, leg 5.

The occurrence of *Eurytemora composita* in an isolated lake of western Asia led Gurney (1931: 186) to suggest its origin from one of the species of the Caspian Sea (*E. affinis, velox, grimmi*). Such a supposition is now difficult to maintain. The wider distribution of the species, as evidenced by its presence on the Bering coast of Alaska and its possible occurrence on the northeast coast of Asia, suggests instead a northern origin. This is supported by the fact that *composita* is closely allied to *E. raboti* Richard, which occurs in fresh and brackish ponds in the Arctic regions (Spitzbergen, Novaya Zemlya, the White Sea coast). The relationship of these two species has been pointed out by Smirnov (1929: 320) and Gurney (1931: 186). The presence of *E. composita* in an isolated brackish lake in eastern Turkestan may be fortuitous or may indicate the western edge of its distributional range.

SUMMARY

A new fresh-water species, *Eurytemora yukonensis*, is described from several localities on the lower Yukon River, Alaska.

Eurytemora composita Keiser is recorded and described from ponds at Unalakleet, Norton Sound, and St. Lawrence Island, Bering Sea, Alaska. It has been known only from eastern Turkestan. Two unidentified males described by Kiefer from the Kuriles, Japan, are similar to the Alaskan material and may be the same species. Since *E. composita* is allied to the Arctic species, *E. raboti*, its occurrence in Alaska suggests a northern rather than a Caspian origin.

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The Bibionidae of New Zealand (Diptera)

D. Elmo Hardy[1]

The family Bibionidae is poorly represented in the New Zealand fauna; only two genera have been recorded to date. These are represented by six species of *Philia* and one species of *Bibio*. The *Bibio* is an Australian species, but the *Philia* species are endemic and known only from New Zealand. It is interesting to note that two of the New Zealand species represent very nearly the minimum and maximum ranges in size for the *Philia* of the world. Specimens of *P. tuthilli* n. sp. range down to about 2.2 mm. in length. I know of only one species in the entire genus which is possibly smaller than this—*P. gratiosa* (Bigot) of India is reputed to be 2.0 mm. in length. Specimens of *P. nigrostigma* (Walker) measure up to 10.0 mm. in length. The only other species which I know that is this large is *P. gigantea* (Macquart) from the Neotropical Region.

This study is based largely upon material which was collected by Dr. L. D. Tuthill of the University of Hawaii and Mr. R. A. Harrison, Entomologist, Department of Scientific and Industrial Research, Auckland, New Zealand. I am indebted to these workers for the privilege of studying this interesting material.

Bibio imitator Walker

Bibio imitator Walker, 1834, Ent. Mag. 2: 470.
B. substitutis Walker, 1848, List. Dipt. Brit. Mus. 1: 121 (? synonym).
B. fulvipennis Macquart, 1850, Dipt. Exot. Suppl. 4: 17.
B. ruficoxis Macquart, 1850, Dipt. Exot. Suppl. 4: 17.
B. elegans Jaennicke, 1867, Abhandl. Senckend. Ges. 6: 317.
B. helioscops Schiner, 1868, Reise Novara, Dipt. 2: 20.

This is the only species of *Bibio* which has been recorded from New Zealand. It is distinguished from other Pacific *Bibio* by the all-black coloring, brown fumose wings, and dense yellow pile on the body of the males and by the all-rufous head, thorax, and abdomen, and the dark reddish-brown to black legs (excluding the coxae) of the females.

LENGTH: Body, 6.5–7.5 mm.; wings, 6.5–8.0 mm.

TYPE LOCALITY: "New Holland."

Type in the British Museum (Natural History). The species occurs in Australia, Tasmania, and New Zealand. I have not seen it from the latter country but have seen a large series of specimens from many localities in Australia.

Key to *Philia* known from New Zealand

1. Wing venation normal, no incomplete veins and crossveins 2
   Venation incomplete, the m crossvein and the bases of veins M_{1+2} and M_1 are lacking; very tiny species, body 2.2–2.63 mm. . . . . *tuthilli* n. sp.
2. Front tibiae each with 3 spines, arranged on a strong prominence at the upper third of the segment, and a single spine situated at the apical two thirds of the tibia (Fig. 5*a*). Wings brownish fumose. Large species, body 6.5–10.0 mm. in length . . . . . *nigrostigma* (Walker)
   Spines on front tibiae not arranged as

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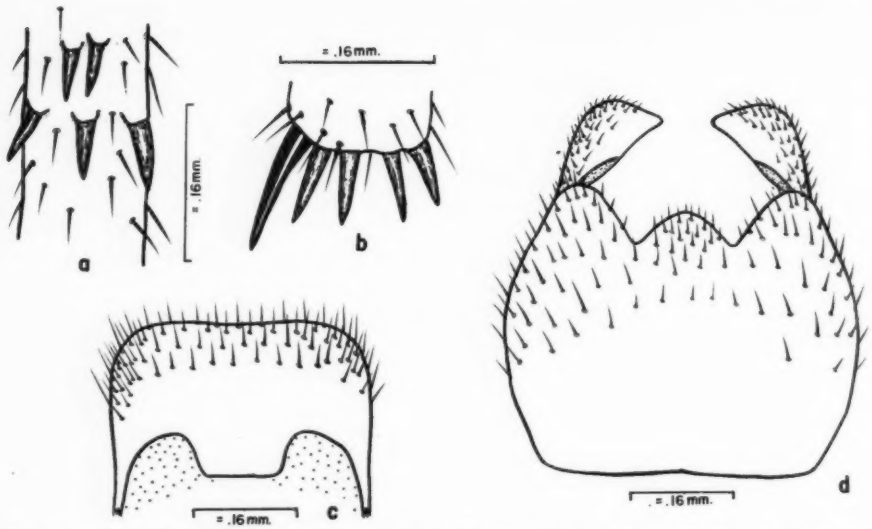

FIG. 1. *P. crinata* Hardy. *a*, Front tibia, median portion; *b*, apical portion of front tibia (lateral aspect); *c*, ninth tergum of male; *d*, male genitalia (ventral aspect).

above. Wings hyaline or but faintly yellowish fumose. Smaller species, body length under 6.0 mm. 3

3. Only 3 spines on each front tibia, above the apical set (Fig. 2*a*) . . . . *harrisoni* n. sp.
Five spines present on front tibia, above the apical set; these are arranged in two groups (Fig. 1*a*) 4

4. The two sets of spines located rather close together near the middle of the tibia (Fig. 1*a*). Apical spurs on the front tibiae much stronger than the spines (Fig. 4*a*). Hind metatarsi of males not broader than apices of tibiae 5
The two sets rather widely spaced, the first is at the basal third of the tibia and the second is near the apical two thirds (Fig. 6*b*). The apical spur about equal in size to the spines (Fig. 6*a*). The hind metatarsi of the males broader than the apices of the tibiae . . . . . *segnis* (Hutton)

5. Pile of body very dense and long, the hairs on the scutellum and in the dorsocentral areas of the mesonotum are about equal to one half the length of the halteres. Wings slightly yellow fumose, posterior veins brownish. Radial vein setulose throughout its length. Tibiae of male yellowish colored, lighter than the femora. The spur at the apex of each front tibia about 1.5 times as long as the apical spines (Fig. 1*b*) . . . . . *crinata* Hardy
Pile rather sparse and short, scarcely extending higher than the spines of the anterior row on the dorsum of the thorax. Wings hyaline, posterior veins colorless. Radial vein nearly bare. Legs of male entirely dark reddish brown to black. The spur on the front tibia twice as long as the apical spines (Fig. 4*a*) *insolita* (Hutton)

Philia crinata Hardy

Fig. 1*a– d*

Philia crinata Hardy, 1951, Hawaii. Ent. Soc., Proc. 14: 262.

This species is related to *P. insolita* (Hutton) but is distinguished by the characters given in the above key and by genital characters (cf. Figs. 1*c*, 1*d*, 4*b*, and 4*c*). The species has

been adequately described except for the genital characters. The antennal segments are more distinctly separated in the specimens at hand than they were in the type series, and the antennae appear to possess 13 segments.

MALE GENITALIA: The ninth sternum is rounded on the sides and is slightly broader than long. The cleft on the hind margin extends about 0.25 the length of the segment and a tumescence is present in the middle of the hind margin. The claspers are rather bluntly pointed on their inner apices (Fig. 1*d*). The ninth tergum is about 1.3 times broader than long, its hind margin is straight, and its posterior margin has a flat-topped projection in the median portion (Fig. 1*c*).

LENGTH: Body and wings, 4.5–5.5 mm.

TYPE LOCALITY: Mt. Wellington, New Zealand.

Type in the United States National Museum.

I have seen additional specimens of this from the following localities in New Zealand: National Park, 4,000 feet, Nov. 6, 1949 (K. P. Lamb), and Waiouru, Oct. 19, 1943, labeled "X galls? on *Olearia virgata*" (D. Hatch). [These would not have come from the galls; they were probably attracted to the plant for feeding.]

Philia harrisoni n. sp.

Fig. 2*a–d*

This species is related to *Philia varipes* (Skuse) from Australia. It is distinguished by the short spurs on the front tibiae (Fig. 2*a*) (equal in size to the apical spines, not twice as long); by the more slender basitarsi of the hind legs (Fig. 2*b*); by the black pilose thorax and abdomen; and by the differences in the male genitalia as shown in Figures 2*c*, *d* and 3*a*, *b*. It is also related to *P. acutidens* (Edwards) but is separated by having only 3 spines in the middle of each front tibia and by the black pilose body.

MALE: Entirely polished black except for a slight rufous tinge in the ground color of the pleura, humeral ridges, tibiae, and tarsi. All pile is dark brown to black. *Head:* The rostrum is about 0.5 as long as the lower portion of the compound eyes and is not produced beyond the bases of the antennae. The antennae

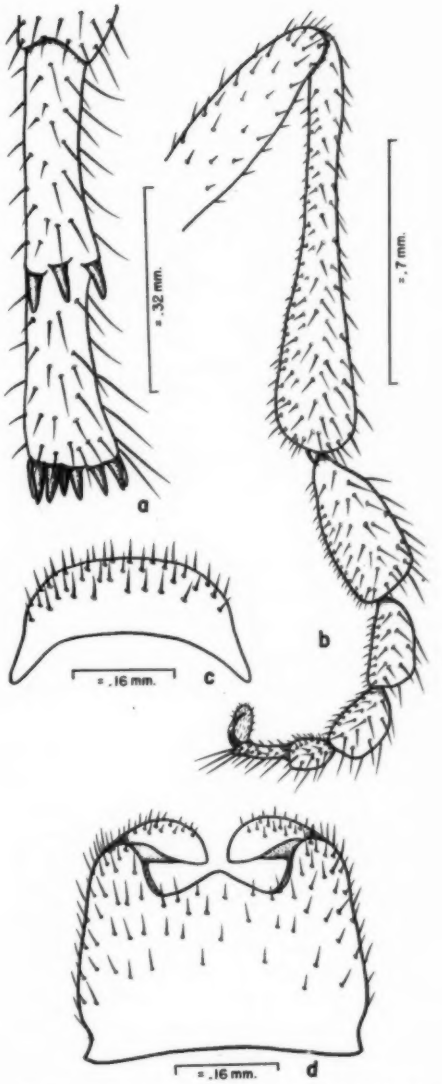

FIG. 2. *P. harrisoni* n. sp. *a*, Front tibia; *b*, hind leg of male; *c*, ninth tergum of male; *d*, male genitalia (ventral aspect).

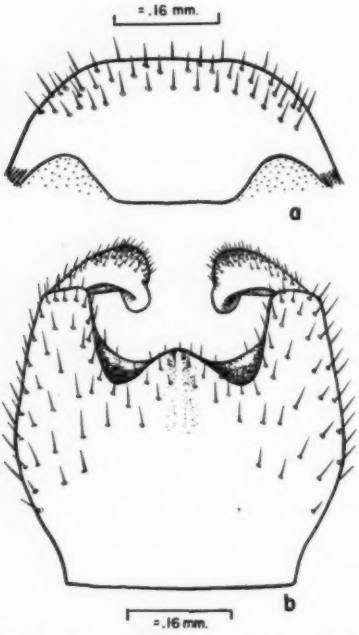

FIG. 3. *P. varipes* (Skuse). *a*, Ninth tergum; *b*, male genitalia (ventral aspect).

are 13 segmented, the apical 4 segments are very closely joined. *Thorax:* With abundant long pile down the dorsocentral areas, around the margins, and on the scutellum. There are 10 teeth in the anterior comb and 12 in the posterior. The stems of the halteres are yellowish, the knobs are dark brown to black. *Legs:* The front tibiae have 3 spines arranged in a transverse row near the middle of the segment. Seven spines are in the apical set and the apical spur is nearly equal in size to the spines (Fig. 2*a*). The hind tibiae are clavate, at their apices they are about equal in width to the widest portion of the femora. The tarsal subsegments are strongly swollen. The basitarsus is not as wide as the apex of the tibia and is about twice as long as wide (Fig. 2*b*). *Wings:* Nearly hyaline, very faintly fumose. The stigma is brown in color and oval in shape. The costa extends to about halfway between the tips of veins Rs and M_1. The anterior veins are brown, and the posteriors are colorless or but slightly yellowed. The venation is typical for the genus. *Abdomen:* About equal in length to the remainder of the body. Compared to *varipes* and related species, the abdomen is rather sparsely pilose. *Genitalia:* The ninth tergum is over twice as broad as long and is straight or very slightly convex on the hind margin (Fig. 2*c*). The ninth sternum is cleft 0.3 to 0.25 of its length on the hind margin and has a tumescence in the middle of this concavity. The claspers are simple and are slightly pointed at their apices (Fig. 2*d*).

LENGTH: Body, 3.6 mm.; wings, 3.8 mm.
FEMALE: Unknown.

Holotype male, Chateau Track, National Park, Feb. 27, 1949 (R. A. Harrison). Eight paratypes, all males: one same data as type; one from Mangatepopo, National Park, Feb. 26, 1949 (R. A. Harrison) and six from "Above Mangatepopo Hut," National Park, Feb. 26, 1949 (R. A. Harrison).

The type and four paratypes have been returned to Mr. Harrison, Department of Scientific and Industrial Research, Auckland, New Zealand. One paratype has been deposited in the British Museum (Natural History), one is at the U. S. National Museum, one in the Bishop Museum, Honolulu, Hawaii, and one is at the University of Hawaii.

Philia insolita (Hutton)

Fig. 4*a–c*

Dilophus insolitus Hutton, 1901, New Zealand Inst., Trans. 34: 193.

This species has been adequately described, except for genital characters, in my paper on the Pacific *Philia* (Hardy, 1951, Hawaii. Ent. Soc., Proc. 14: 264–265). It is related to *P. segnis* (Hutton) and *P. crinata* Hardy and is distinguished by the characteristics given in the above key and by the male genitalia as in Figures 4*b*, *c*, 6*c*, 1*d*, and as described below.

MALE GENITALIA: The ninth tergum is about 1.3 times as wide as long, and the hind margin

is straight or nearly so (Fig. 4*b*). The ninth sternum is about as broad as long, and the cleft on the hind margin extends about 0.25 the length of the segment. The claspers are sharp pointed on their inner apices (Fig. 4*c*).

LENGTH: Body and wings, 4.3–5.5 mm.

TYPE LOCALITY: Christchurch.

The type is in the Canterbury Museum, Christchurch.

I have previously recorded this species from several localities in New Zealand.

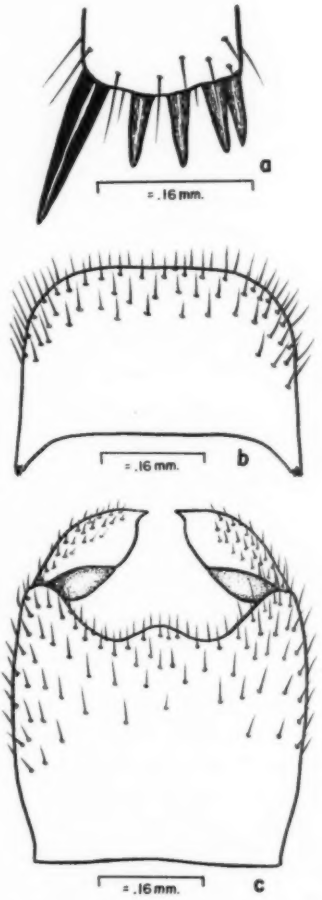

FIG. 4. *P. insolita* (Hutton). *a*, Apex of front tibia (lateral aspect); *b*, ninth tergum of male; *c*, male genitalia (ventral aspect).

Philia nigrostigma (Walker)

Fig. 5*a–c*

Bibio nigrostigma Walker, 1848, Cat. Dipt. Brit. Mus., p. 121.

B. zealandicus Walker, 1858, Ent. Soc. London, Trans. (n.s.) 4: 235. New synonymy.

Dilophus spectabilis Nowicki, 1875, Krakauer K. K. Akad. d. Wissen., Mem. 2: 10.

Bibio zealandicus Walker has been previously treated as a variety of *nigrostigma*, distinguished from the typical form by having the abdomen of the female ferruginous below instead of black. The coloration of the females has been found to be so variable that it does not appear practical to recognize this variety. This species has been adequately described, except for the genital characters, in my paper on the Pacific *Philia* (Hardy, 1951, Hawaii. Ent. Soc., Proc. 14: 268–270). It can be readily distinguished from the other New Zealand species by its large size, the brown fumose wings, and the arrangement of the spines on the front tibiae (Fig. 5*a*).

MALE GENITALIA: The ninth tergum is nearly twice as wide as long and is gently concave on its hind margin (Fig. 5*b*). The posterior lateral margins of the ninth sternum are produced into a pair of short lobes which extend about halfway to the apices of the claspers. The claspers are large and conspicuous and are enlarged at their apices and shaped like a hammer head (Fig. 5*c*). The ninth sternum is slightly broader than long.

LENGTH: Body and wings, 6.5–10.0 mm.

TYPE LOCALITY: "New Zealand."

The type is in the British Museum (Natural History).

I have previously recorded this species from several localities in New Zealand. Specimens have since been seen from the following: Southeast of Taupo, 3,000 feet, Dec. 7, 1949 (L. D. Tuthill); Mt. Wellington, Lava Fields, Nov. 12, 1948 (S. A. Rumsey); Owairaka, Nov. 16, 1940 (D. Spiller) and Avondale, Auckland, Dec., 1949 (R. A. Harrison).

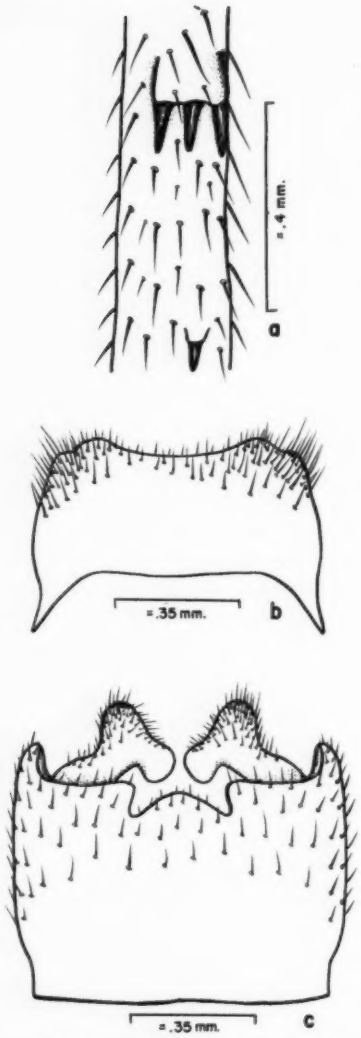

FIG. 5. *P. nigrostigma* (Walker). *a*, Front tibia, median portion; *b*, ninth tergum of male; *c*, male genitalia (ventral aspect).

Philia segnis (Hutton)

Fig. 6*a–c*

Dilophus segnis Hutton, 1901, New Zealand Inst., Trans. 34: 194.

This species is related to *P. insolita* (Hutton) but is distinguished by the arrangement of the spines on the front tibiae (Fig. 6*b*); by the small, poorly developed apical spurs of the front tibiae (Fig. 6*a*); and by having the hind metatarsi of the males more strongly swollen, broader than the apices of the tibiae. The ninth tergum is twice as wide as long, and the hind margin is very slightly concave (Fig. 6*c*). The ninth sternum and the claspers are shaped as in *P. insolita* (Fig. 4*c*). For further descriptions and figures of this species see Hardy, 1951 (Hawaii. Ent. Soc., Proc. 14: 272–273).

LENGTH: Body, 4.5–5.0 mm.; wings, 4.0–4.2 mm.

TYPE LOCALITY: Christchurch, New Zealand.

The type is in the Canterbury Museum, Christchurch.

I have previously recorded this species from several localities in New Zealand. Two female specimens have recently been seen which appear to be this species; they were from Blenheim, Nov. 15, 1942 (D. Spiller) and Titirangi, Auckland, Oct. 2, 1949 (E. Bray).

Philia tuthilli n. sp.

Fig. 7*a–f*

This remarkable species is readily differentiated from any known member of the genus *Philia* by its incomplete wing venation. This is the only species which I have seen from the entire world which lacks the m crossvein (posterior crossvein) and which has the bases of veins M_{1+2} and M_1 evanescent (Fig. 7*d*). This is also one of the smallest species of *Philia* which has been recorded, and the shape of the head (Fig. 7*a*) is unique for this genus.

MALE: Tiny, chiefly shining black species with a faint, reddish tinge in the ground color of the pleura, humeral ridges, scutellum, and legs. Pile all black. *Head:* The upper portion of each compound eye is brownish red and is densely covered with short pile; the lower part of each eye is black. The front margins of the compound eyes are produced beyond the bases of the antennae and completely ob-

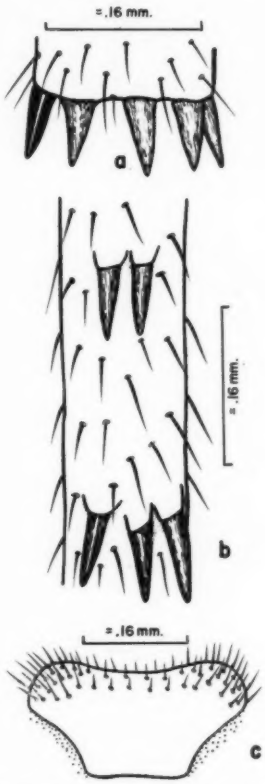

FIG. 6. *P. segnis* (Hutton). *a*, Apex of front tibia (lateral aspect); *b*, front tibia, median portion; *c*, ninth tergum of male.

scure the basal 3 or more segments in most specimens (Fig. 7*a*). The face is not at all produced, its margin is sunken below the eye margins and is not visible from a lateral view. The antennae are apparently about 9 segmented. The flagellum is clavate in shape, and the segments are so closely joined that they cannot be accurately counted. The antennae project downward (Fig. 7*a*) rather than upward as is the usual condition in *Philia*. The labella and palpi are largely hidden beneath the margins of the compound eyes. *Thorax:* With rather long black dorsocentral and marginal hairs. The scutellum has long hairs around its hind margin. The halteres are black except for a yellowish tinge on their bases. *Legs:* With all segments slender. The front tibiae have two sets of spines, composed of two spines each, above the apical set. The first two spines are close together and are situated at about the basal one third of the segment. The second set has the spines more widely spaced and situated near the apical two thirds of the segment (Fig. 7*b*). The apical spur is small, approximately equal in size to the spines. The segments of the hind tarsi are slender, not at all swollen. *Wings:* Very faintly tinged, almost hyaline. The stigma is light brown and is oblong in shape. The anterior veins are dark brown, the posteriors are hyaline to faintly yellowish. The costa extends about 0.4 the distance between veins Rs and M_1. The m crossvein and the bases of veins M_{1+2} and M_1 are completely lacking (Fig. 7*d*). Except for the basal portion, the anal vein is represented only by a slight fold in the wing. The shape of cell R is very different from that of other *Philia*. The r-m crossvein is more nearly longitudinal in position, and there is no sharp angle at the point of junction of the r-m and vein M_{1+2}. Veins M_{1+2} and Rs give the appearance of being a single continuous vein (Fig. 7*d*). *Abdomen:* About twice as long as the thorax and sparsely pilose. *Genitalia:* The ninth tergum is about twice as wide as long. The anterior margin is straight, or nearly so, and the posterior margin is convex (Fig. 7*e*). The sternum is about as wide as long and has a small tumescence in the middle of the hind margin. The concavity on the hind margin extends about 0.25 the length of the segment. The claspers are rather sharply pointed at their apices (Fig. 7*f*).

LENGTH: Body, 2.63 mm.; wings, 2.26 mm.

FEMALE: *Head:* Of usual shape for genus, the sclerotized portion in front of the eyes is about 0.3 as long as the eyes, and the portion behind the eyes is nearly as long as the eyes. The antennae appear to be 10 or 11 segmented. The segments are very closely joined and are difficult to discern as in the male. The ocellar tubercle is not well devel-

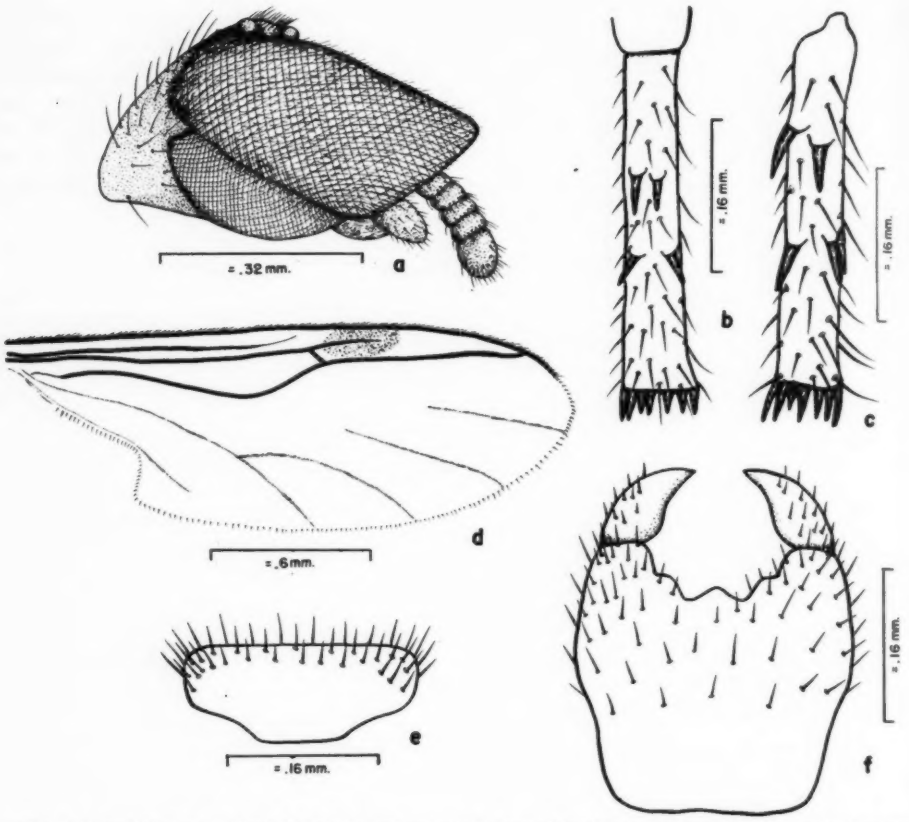

FIG. 7. *P. tuthilli* n. sp. *a*, Head of male (lateral aspect); *b*, front tibia of male; *c*, front tibia of female; *d*, wing; *e*, ninth tergum of male; *f*, male genitalia (ventral aspect).

oped and extends only the height of the ocelli above the level of the vertex. The head is entirely polished black and is sparsely brown to black pilose. *Thorax:* Chiefly polished black, tinged with red. The propleura and the area of the dorsum between the combs are rufous tinged with brown. The anterior comb contains 12 blunt teeth, the posterior comb 10 sharp teeth. *Legs:* The front coxae and the bases of all the femora are rufous. The remainder of the legs are brown to black, tinged with red. The spines on the front tibiae are much stronger than in the males and 3 spines are present in the middle set; 2 spines placed one above the other on the outside dorsal surface and 1 spine placed on the inner dorsal surface (Fig. 7*c*). The extra spine on the females is smaller than the others and it possibly may occur, at least as a rudiment, in the males. I have been unable to detect it on the specimens at hand but the smaller spines of the males are sometimes difficult to differentiate; in small species a tiny spine could easily be obscured by the bristles of the legs. *Wings:* Slightly more fumose than in the males. *Abdomen:* Brown, tinged with red. The abdomen is sparsely covered with short black pile.

LENGTH: Body, 2.2–2.45 mm.; wings, 2.5–2.65 mm.

HOLOTYPE male, allotype female, and twen-

ty paratypes (ten males and ten females): Lake Taupo, New Zealand, Feb. 20–22, 1950 (L. D. Tuthill).

The type, allotype, and a series of paratypes are being deposited in the Cawthron Institute, Nelson, New Zealand (at Dr. Tuthill's request). The paratypes are in the following collections: U. S. National Museum, British Museum (Natural History), Bishop Museum, Honolulu, and the University of Hawaii.

NOTES

Hawaii as a Cloud Physics Laboratory

The major islands of the Hawaiian chain lie across the Pacific northeast trade winds near north latitude 21°, about 2,400 miles southwest of San Francisco. It is the purpose of this note to discuss very briefly the great advantages of one of these islands (Hawaii) as a place to study the relationships between the precipitation elements in clear marine air and these elements present in clouds formed in this air.

Recent developments in the study of rain formation have led to the hypothesis that large sea-salt particles are the basic nuclei upon which many raindrops initially form (Ludlam, 1951, Quart. Jour. Roy. Met. Soc. 77: 402–417; Woodcock, 1952, Jour. Met. 9: 200–212; Squires and Woodcock, MS.). These developments have re-emphasized the need in cloud physics for further detailed physical-chemical studies of rain which will enable us to ". . . know how nature operates to produce precipitation" (Byers, 1953, Indian Acad. Sci., Proc. 37(A): 237–247).

In order to make preliminary tests of the salt particle-raindrop hypothesis by making measurements of natural rains, it was necessary to find a geographic location where the contents of the lower atmosphere could be determined before, during, and after the formation of cloud and rain. Recent work has indicated that the windward side of the island of Hawaii, in the region of Hilo, is almost ideal for this study (see Fig. 1). Here, on most of the days throughout the year, rain falls near area A from orographic clouds which have formed over the island and within the trade-wind stream. If one follows the streamlines of this trade-wind air upwind of area A and over the sea, only scattered cumulus clouds are found upon arrival near area B. If the air is followed downstream from A, the clouds are found to dissipate, leaving clear air at C. Hence it is possible to determine, by appropriate measurement, the contents of a parcel of clear air at B, the nature of the precipitation within clouds formed in this air when it arrives at A, and the final modified parcel after the clouds have dissipated at C, a distance of about 30 miles.

Much of the mountain slope near Hilo is readily accessible on paved roadways. Rain and cloud drop sizes may be sampled within the orographic clouds from the 2,000 foot level to the 6,500 foot level on these roadways, thus avoiding the problems of evaporation, accretion, etc., which can greatly modify rains falling through clear air from cloud base to ground.

The presence of the trade-wind inversion at an average height of about 6,000 feet over the sea concentrates the clouds and water vapor in the lower air (Riehl *et al.*, 1951, Quart. Jour. Roy. Met. Soc. 77: 598–626; U.S. Weather Bureau, Staff Members, Honolulu, MS.; Leopold, 1949, Jour. Met. 6: 312–320). The inversion also limits the vertical extent of the salt nuclei, as shown in Figure 2. The distribution curves representing salt particles at the 1,550 and 2,740 meter altitudes show a great reduction in the number and weight of particles at the base of the inversion and above it (see temperature on insert diagram,

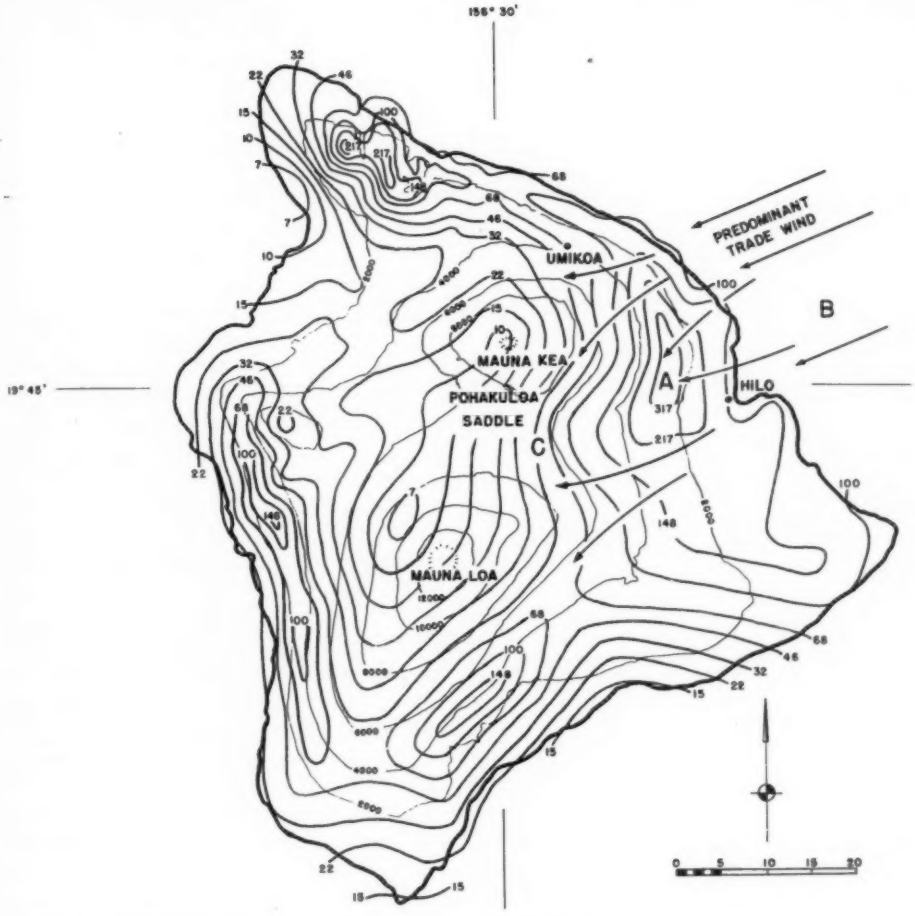

FIG. 1. Streamlines and mean annual rainfall on NE part of Hawaii. Isohyetal lines are in inches. The arrows represent the hypothetical mean streamlines of the flow of the trade winds in this part of the island, as given by Leopold (1949). (Scale in statute miles.)

Fig. 2). This concentration of the precipitation elements (i.e., clouds, water vapor, and nuclei) in the lower air is found during most of the year in this area and is one of the major advantages of Hawaii for precipitation studies such as those discussed here. Measurements of water vapor, temperature, salt nuclei, etc., can therefore be limited to the lower atmosphere, and there is usually no need to be concerned with the higher levels.

A further result of the presence of the trade-wind inversion is that the great majority of the clouds never ascend to heights at which the temperature is below freezing. Thus, most of the time there is no confusion as to whether or not the Bergeron rain-forming process may have occurred. It seems clear that accretional processes must account for practically all the rains in this region, and hence it is an excellent area in which to attempt to relate the

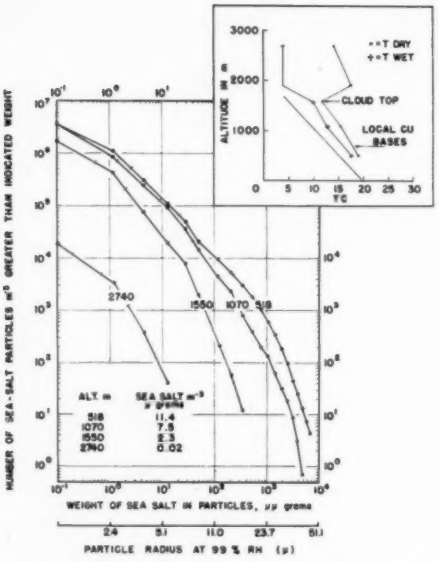

FIG. 2. Vertical distribution of sea-salt particles over the sea in Hawaii (21°30′N, 157°40′W), May 30, 1952, 1300 local time. Surface wind 80°, force 4 to 5. Height of scattered cumulus cloud bases varied from 690 to 820 meters. Temperature at 2,740 meters 12.8°C. The short transverse lines on the distribution curves mark the first quartile, median, and third quartile weight distribution points, reading left to right. The distribution curves are read as follows: at a height of 518 meters there are about 10,000 particles larger than 100 $\mu\mu$ grams.

detailed physical changes in the air associated with these frequently recurring processes.

The presence of the great mountain Mauna Kea (see Fig. 1), extending up to almost 14,000 feet, makes it possible to obtain direct visual estimates of maximum cloud heights among the orographic clouds over the high-rainfall region during extended time periods which make air craft observation impracticable. These estimates can be made at the same time that rain and cloud drops are being sampled within the cloud along the roadway below. One can drive a car up to a point at the 9,500 foot level, which is near a site overlooking the high-rainfall region A.

In this area of Hawaii, nature is producing rain very regularly and under simple conditions usually uncomplicated vertically by multiple layering of air masses of different origin and physical history. Geophysical events of the past and present seem to have fortuitously conspired to produce a setting in which simple natural experiments in rain-making are an almost daily occurrence. Through the use of local roadways and aircraft, the whole experimental area is readily accessible for study, and the observations of one day can commonly be tested or extended on the following day under the nearly constant natural conditions. The author knows of no other geographical setting so uniquely advantageous for cloud physics studies.

The importance of rainfall to the economy of the Hawaiian Islands has led to extensive activity by local organizations in the study of various weather factors and in the accumulation of data from numerous observing stations. These organizations—the U. S. Weather Bureau, the Pineapple Research Institute, the Experiment Station of the Hawaiian Sugar Planters' Association, and the Territorial Cattlemen's Council—located at Honolulu, Hawaii, are interested in fostering cloud physics research and are able to supply valuable climatological data from long-period records as well as current radiosonde and other data from numerous local stations. — *A. H. Woodcock, Woods Hole Oceanographic Institution.* (Contribution No. 660 of the Woods Hole Oceanographic Institution.)

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